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Implications of Services-Oriented Architecture and Open Architecture composable systems on the acquisition organizations and processes

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THESIS

IMPLICATIONS OF SERVICES-ORIENTED ARCHITECTURE AND OPEN ARCHITECTURE COMPOSABLE SYSTEMS ON THE ACQUISITION ORGANIZATIONS AND PROCESSES

by

Cory S. Brummett
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June 2008

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13. ABSTRACT (maximum 200 words)

The U.S. Navy is interested in acquiring systems that promote the use of Services-oriented Architecture (SOA) and Open Architecture (OA) in Integrated Warfare Systems (IWS). The number of systems required to share data and provide reliable information in weapons systems is growing. Many systems, systems-of-systems and families of systems with different software architectures are acquired and often have difficulty operating together, which causes delays, increases costs, and limits re-use. Intelligent adoption of SOA and OA may help solve integration and reuse issues in current and future acquisition programs. The commercial market is successfully beginning to implement SOA and OA in their processes and may provide examples of best practices that can be applied to the Defense Acquisition System. The goal of this thesis is to explore the feasibility of implementing SOA and OA into the Defense Acquisition System. Adoption of SOA and OA practices is not expected to completely alter the current Defense Acquisition System; instead, it is intended to alleviate some of its constraints. This thesis will focus on utilizing SOA and OA in IWS, how SOA and OA principles relate, and the effects they will have on the Defense Acquisition System's organizations and processes.

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ACRONYMS AND ABBREVIATIONS

ACAT	Acquisition Category
AIS	Automated Information Systems
AOP	Aspect-Oriented Programming
ASN(RD&A)	Assistant Secretary of the Navy, Research, Development and Acquisition
AT&L	Acquisition, Technology and Logistics
BPM	Business Process Management
C4I	Command, Control, Communications, Computers, Intelligence
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CANES	Consolidated Afloat Networks Enterprise Services
CDD	Capability Development Document
CGX	Guided Missile Cruiser (X)
CID	Combat Identification
CIO	Chief Information Office
CM	Configuration Management
CONOPS	Concept of Operations
COTS	Commercial Off The Shelf
CPD	Capability Production Document
DAE	Defense Acquisition Executive
DAU	Defense Acquisition University
DNI	Director of National Intelligence
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DON	Department of the Navy
DOTMLPF	Doctrine, Organization, Training, Material, Leadership and Education, Personnel and Facilities
EAI	Enterprise Application Integration
EXCOMM	Executive Committee
GIG	Global Information Grid
IA	Information Assurance
ICD	Initial Capabilities Document
IT	Information Technology
IWS	Integrated Warfare Systems

JCIDS	Joint Capabilities Integration and Development System
KPP	Key Performance Parameters
MDA	Milestone Decision Authority
MOSA	Modular Open Systems Approach
MOU	Memorandum of Understanding
NOA	Naval Open Architecture
NSS	National Security Systems
OA	Open Architecture
OAAM	Open Architecture Assessment Model
OAAT	Open Architecture Assessment Tool
OAC	Open Architecture Council
OAET	Open Architecture Enterprise Team
OPNAV	Office of the Chief of Naval Operations
OSD	Office of the Secretary of Defense
OSJTF	Open Systems Joint Task Force
PART	Program Assessment Review Tool
PEO-IWS	Program Executive Officer Integrated Warfare Systems
PM	Program Manager
PPBE	Planning, Programming, Budgeting and Execution System
QoS	Quality of Service
RFI	Request for Information
RFP	Request for Proposals
ROI	Return on Investment
S&T	Science and Technology
SDS	System Design Specification
SE	Sustained Engineering
SOA	Services-oriented Architecture
SPAWAR	Space and Naval Warfare Systems Center
SYSCOM	Systems Command
T&E	Test and Evaluation

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I. INTRODUCTION

A. PURPOSE

The purpose of this thesis is to analyze whether the Defense Acquisition System needs to be altered to take advantage of the implementation of Services-oriented Architecture (SOA) and Open Architecture (OA) principles into the acquisition of Integrated Warfare Systems (IWS). To accomplish this, the researchers will examine SOA and OA principles, processes and objectives; the Defense Acquisition System and the acquisition lifecycle; and the best practices of an emerging Naval acquisition program and its SOA implementation. The objective of this thesis is to discuss and generalize from the analysis any necessary realignment of the Defense Acquisition System and the acquisition lifecycle to allow new technology acquisition in military organizations that will benefit future IWS programs.

B. BACKGROUND

The United States Navy is attempting to restructure its defense enterprise in a manner more suitable to the current threat environment and evolving future threats. The Navy is trying to furnish the warfighter with the appropriate tools to defend against emerging threats. Over the last few decades, the Navy, along with the rest of the Department of Defense (DoD), has increasingly integrated itself by developing joint warfighting concepts, organizations, training and operations. However, updates to the Navy and the DoD acquisition policies, processes and practices have lagged behind, which has impeded the integration effort. Recent experiences have demonstrated the need for the Navy and the DoD to integrate their acquisition policies, processes and practices in order to foster joint acquisition solutions for the warfighting needs of tomorrow.

The Congressional Budget Office has estimated an $895 billion decrease in defense spending between 2005 and 2014 (PEO-IWS 7.0 & the OA Enterprise Team, 2007, p. 8). As competition for acquisition dollars becomes increasingly strenuous, the

Navy is challenged with difficult budget decisions. With inflexible acquisition strategies, the Navy has become locked into single systems and vendors that limit the options for competition and innovation. The Navy has acquired systems that have performed their functions and tasks exceedingly well; however, the Navy's vertical "stove-piped" combat systems tend to be localized, preventing the sharing of information and technology across the different combat system programs. Acquiring combat systems using legacy processes and principles leads to the acquisition of combat systems that have duplicative capabilities, yet are incompatible and not interoperable. Each combat system is unique to the platform for which it was designed. These vertical "stove-piped" combat systems, the policies, processes, and practices, along with the information technology (IT) designed to implement these systems have become an increasingly tighter constraint within the acquisition process. The Navy has taken steps to diminish the utilization of vertical "stove-piped" combat systems infrastructure and to shift to a more dynamic, horizontal combat systems infrastructure that takes advantage of advances in IT.

The Navy is continually seeking new ways to develop, field and support its sophisticated combat systems in order to meet the future needs of the warfighter. In order to keep up with advances in technology, the Navy has transitioned from the traditional detailed MILSPEC development model to an approach that stresses open systems and the use of commercial standards and commercial off-the-shelf (COTS) hardware and software. The United States Navy is becoming increasingly interested in the acquisition of IWS that utilizes Open Architecture (OA). Open Architecture is a confluence of business and technical principles that, when correctly applied, yields modular, interoperable systems that employs widely accepted standards and published interfaces that lead to options for greater competition and inclusion of innovators (Navy Office of Information, 2006).

An OA approach combines business and technical principles and practices that, taken to their logical conclusion, will change the acquisition paradigm but will not provide the Navy with solutions for solving the vertical to horizontal acquisition process. Joseph Uchytil's Naval Postgraduate School thesis, *Assessing the Operational Value of Situational Awareness of AEGIS and Ship Self-Defense System (SSDS) Platforms through*

the Application of the Knowledge Value Added (KVA) Methodology, demonstrated the operational benefits and the Return on Investment (ROI) that could be realized through the application of an OA approach to systems design. Jameson R. Adler and Jennifer L. Ahart's Naval Postgraduate School thesis, *AEGIS Platforms: Using KVA Analysis to Assess Open Architecture in Sustaining Engineering*, builds on Uchytil's research by assessing the impact of implementing an OA development and acquisition approach to Sustained Engineering (SE) in IWS. Adler and Ahart demonstrated the benefits of OA and the ROI gained from implementing OA within SE, and they laid the foundation for the possible implementation of Services-oriented Architecture to eliminate organizational "stove-pipes" within the acquisition process.

SOA development practices may provide the framework and the components to more efficiently develop architectures more conducive to future IWS. "SOA establishes an architectural model that aims to enhance the efficiency, agility, and productivity of an enterprise by positioning services as the primary means through which solution logic is represented in support of the realization of strategic goals associated with service-oriented computing" (Erl, 2008a, p. 38). SOA is not an entirely new IT paradigm; it merely approaches silo-based problems by building on previously proven development processes by introducing agnostic services, which allows for increased horizontal integration (p. 84). This thesis will build on the past work of Uchytil, Adler and Ahart by examining the implications of implementing SOA and OA within the Defense Acquisition System.

C. RESEARCH OBJECTIVES

The research conducted for this thesis encompasses several objectives. The first objective is to examine the relational architecture between SOA and OA systems. The second objective is to review the Defense Acquisition System to determine the feasibility of moving toward SOA and OA systems. The third research objective is to identify any possible constraints within the Defense Acquisition System that may prevent an SOA and OA approach in IWS. The fourth research objective is to examine best practices of Naval acquisition programs that are currently incorporating SOA and OA into their acquisition

processes. The fifth and final objective of the research is to examine potential re-alignments of the Defense Acquisition System that will allow new technology acquisition in military organizations.

D. RESEARCH QUESTIONS

This thesis attempts to provide constructive, educational and useful answers to Navy IT decision-makers for three questions, as well as providing recommendations concerning the direction in which the Navy and the DoD may wish to proceed in the future when acquiring systems that benefit horizontally across multiple acquisition programs.

- Does the Defense Acquisition System need to be altered to take advantage of SOA and OA implementation into the acquisition lifecycle?
- Do current Navy OA policies and SOA practices provide the necessary interoperability requirements for future IWS?
- What benefits might SOA and OA provide to IWS?

E. METHODOLOGY

In order to provide a better understanding of SOA and OA and their relationships, this research paper first provides a general overview of SOA and OA concepts. In order to accomplish this, the authors will conduct a literature review of SOA and OA. They will then examine the Defense Acquisition System by conducting a literature review of DoD and Naval acquisition policies and initiatives. Next, there will be an analysis of organizational utilization of SOA and OA and a development of a mini case study based on current SOA implementation for the Consolidated Afloat Networks and Enterprise Services (CANES) project. The end result of this thesis will be to develop recommendations based on findings in the literature reviews and analysis of the mini case study.

F. SCOPE

This research will address the principles, processes and objectives of SOA and OA frameworks, as well as their relationships and how they can be integrated into the Defense Acquisition System. It will include a literature review of SOA and OA, in addition to providing an overview of the current Defense Acquisition System. The SOA development process for CANES will be examined, with concentration on the planning and implementation of the core services.

G. THESIS ORGANIZATION

Chapter I has provided a general overview of the problem, explained the research objectives, introduced the thesis questions, and defined the methodology and scope. Chapter II will provide research and background information on Services-oriented Architectures, Open Architecture and the relationship between them. Chapter III will consist of a review and evaluation of the current Defense Acquisition System, SOA and OA requirements, and an analysis of a transition from the vertical “stove-piped” acquisition process to a horizontal acquisition process. Chapter IV will provide a discussion and analysis of a current Navy acquisition program incorporating SOA and OA into its acquisition process. Chapter V will contain conclusions and recommendations as well as topics for future research.

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II. LITERATURE REVIEW: SERVICES-ORIENTED ARCHITECTURE AND OPEN ARCHITECTURE

A. SERVICES-ORIENTED ARCHITECTURE (SOA)

This section provides a definition of Services-oriented Architecture (SOA), discusses some SOA influences, outlines SOA concepts and principles, and discusses some benefits and challenges of SOA.

1. Definition

Services-oriented Architecture (SOA) is defined differently by many organizations. The absence of a concrete definition may allow organizations to more easily adapt an SOA to their current business processes. Simply defined, SOA is "an architecture for a system or application that is built using a set of services" (O'Brien, Bass, & Merson, 2005, p. 3). Examples of varying SOA definitions are listed below.

- An SOA is "a set of components which can be invoked, and whose interface descriptions can be published and discovered." (W3C, 2004)
- "The SOA models the business as a collection of self-contained services that are available across the enterprise that can be evoked through standard protocols both internally and externally." (McComb as cited by Mimoso, 2004)
- "Service Oriented Architecture (SOA) is an approach to the development of loosely coupled, protocol-independent distributed applications composed from well-defined, self-contained software resources accessible as Services across the extended enterprise in a standardized way, enhancing re-usability and interoperability." (Gupta as cited by Mimoso, 2004)
- "SOA is an approach to building software applications as collections of autonomous services that interact without regard to each other's platform, data structures, or internal algorithms." (Champion as cited by Mimoso, 2004)

Although the definition of SOA varies in the information technology industry, some basic and useful concepts may be utilized to improve processes. Re-use,

interoperability, availability, and standard interface protocols across an entire enterprise are key business concepts that may prove beneficial in United States Naval platforms. Many organizations already employing an SOA are streamlining their processes to reduce redundancy, thereby reducing costs.

2. Service Definition

"A service is an implementation of a well-defined piece of business functionality, with a published interface that is discoverable and can be used by service consumers when building different applications and business processes" (O'Brien et al., 2005, p. 1). This definition gives a broad overview of a service but can be built upon to better understand what services can do for an organization. Services are also relatively isolated from other services, and they also can provide a "collection of capabilities," not just a single capability. Capabilities with a common function may be contained in a single service, such as a shipment service. The shipment service would incorporate the get, add, and report capabilities (Erl, 2008a, pp. 69-70). Organizations must understand the capabilities of each service composed in their SOA to reduce redundancy and to promote re-use and interoperability.

3. SOA Influences

"While reuse, especially over time, can be one of the most rewarding parts of investing in SOA, it is not the sole primary benefit. Perhaps even more fundamental to service-orientation than promoting reuse is fostering interoperability" (Erl, 2008a, p. 90). SOA is not a design paradigm that materialized out of thin air; rather, it is influenced by previous design paradigms and technologies that leverage the best practices from each to provide greater interoperability and increase the re-use potential. Figure 1 depicts the design paradigms and technologies that represent the primary influences of service-orientation. SOA draws successful and proven approaches from these past paradigms and couples them with emerging IT principles. SOA remains in a state of evolution and continues to be influenced by the newest technology innovations.

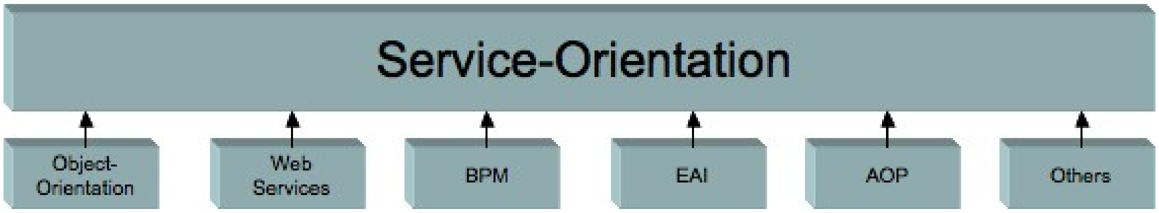

Figure 1. Primary Influences of Service-orientation from (Erl, 2008a, p. 97)

4. Re-use

Re-use provides advantages by allowing the same or similar process use in various architectures, systems, or applications. The use of previously proven concepts reduces development and implementation times. Additionally, re-use provides the ability to use the same service among platforms that have overlapping missions. Utilizing agnostic services across multiple platforms reduces system complexity and future redesign costs.

Re-use is an enabler to service composition. As re-use potential increases, so do the available compositions. Services should not be developed for particular compositions; rather, they should be developed to operate in numerous compositions. As service inventories for Naval Integrated Warfare Systems (IWS) mature, the desire is to allow multiple applications on multiple platforms to use common services. Services designed for IWS should be agnostic enough to operate across multiple systems. Correctly designed services will provide the necessary compositions required for evolving Navy IWS requirements.

Historically, re-use has been highly desired in the software industry but often difficult to achieve. Typically, "reuse increases the complexity, cost, effort, and time to build software" (Erl, 2008a, p. 257). Some reasons these attributes exist are that software designers are designing applications to fulfill requirements for a specific process or only to solve immediate problems. Return on investment (ROI) is easier to calculate when using single purpose applications. Each application has measurable inputs and outputs that equate to an understandable ROI. "This type of reasoning is what has led to the

popularity of siloed application environments" (p. 257). The difficulty associated with calculating ROI of reusable services is more complex, and the benefits may not be realized at initial service implementation. As a service is re-used and new service compositions are formulated, the ROI will continue to increase, as illustrated in Figure 2.

Figure 2. Example of ROI for SOA Projects from (Erl, 2008a, p. 62)

The re-use concept requires a shift from traditional system development and also requires stakeholders and architects to look horizontally across multiple systems and consider future requirements that may benefit from re-use.

Many Naval systems are currently developed vertically or in "silos." This has led to redundant applications and escalating costs. Re-use among IWS can alleviate long-term cost burdens and streamline systems. SOA provides design principles to guide Navy IWS toward more agile systems that provide better interoperability and future cost reductions. There are differing viewpoints on how to calculate ROI for SOA, which will be discussed later in this chapter.

5. Interoperability

Common services provide seamless interaction with new and legacy systems, regardless of platform specific characteristics. SOA uses interfaces to allow data sharing between systems that were unable to communicate in the past. As legacy systems are encapsulated and enter into the SOA-based framework, interoperability becomes more transparent. Reuse is directly related to interoperability. As service reuse increases, interoperability increases, providing a less burdensome IT structure.

6. Availability

Availability is the rate at which services are accessible. SOA provides the advantage of constant availability since single components are responsible for compartmentalized data. Service availability is crucial in Naval Integrated Warfare Systems. With multiple entities relying upon a given service, degraded availability may occur. Complete loss of a high-demand service affects all applications subscribing to that service. Backup services should be considered when designing an SOA around critical systems.

7. Interface

Interface protocols are becoming standard across industries. The Navy can use proven standard interface protocols to integrate legacy systems into services-oriented systems. Common interface protocols allow services to provide data to different platforms, thereby increasing an enterprise's agility (Gorton, 2006, p. 152). "Agility, on an organizational level refers to the efficiency with which an organization can respond to change" (Erl, 2008a, p. 63). Agility refers to how quickly services in an organization can be composed and has nothing to do with how quickly services can be developed. As agility increases, interoperability increases due to standard interface protocols and the time to change system components is reduced.

Services are linked by service contracts. Service contracts allow services to communicate and "establishes the terms of engagement, providing technical constraints and requirements as well as any semantic information the service owner wishes to make public" (p. 126). Service contracts allow the owner to permit customers to see only the logic required to establish use, while allowing a service to remain abstract enough to reduce service dependency. Service contracts should address how a service is used and also address the composability of that service.

8. Service Location

Once services are developed and deemed essential components for a given architecture, service location must be addressed. Some systems may require services located in closed environments, such as aboard ships–where only applications internally related have access to the services–while other systems may subscribe to services external to their environment.

In closed systems with known services and service locations, each service is accessed by one or more applications but with limits on the number of applications subscribing to each service.

Open systems that subscribe to external services need the ability to process requests from large numbers of subscribers. Concerns for excessive latency, varying application interfaces, and service availability may decrease service reliability.

Before developing any SOA, the stakeholders must determine which services are required, their locations, how they are accessed, and which services are mission-critical. Ideally, a system is built from existing services to easily develop an SOA that provides desired system functions. Required services that do not exist must be developed to provide desired functions and should be agnostic, allowing subscription from other systems and applications. Service location limits re-use and accessibility.

Different SOAs use varying applications and require interface protocols for service subscription and the service contracts they use. Determining service type and location determines the application interface.

Latency and availability issues in mission-critical systems require risk-mitigation solutions. Latency problems surface as subscription increases for a given service. Increased latency may lead to unacceptable reduced availability in mission-critical systems. Mission-critical systems require additional services or duplicate services to mitigate risk if runtime issues cannot be overcome.

9. Loose Coupling

Loose coupling refers to the dependency of services upon each other. An SOA design goal is to reduce the dependency between services, while still providing interoperability within a system. It is desirable to have just enough coupling to maintain interoperability, while reducing dependency. As the dependency loosens, re-use potential is improved, which allows service design more flexibility. Although loose coupling is desired in an SOA, interoperability–as stated earlier–has greater importance. Services should only have reduced dependency to a degree that they still allow interoperability between multiple services and across multiple applications.

10. SOA Design Standards

Design standards are central to SOA development. Although design standards in the information technology environment often require significant establishment time, they also provide for more efficient designs. Design standards are not necessarily new information technology standards; they can be data standards or interface standards that currently exist. These standards will allow an organization to better understand the architecture being pursued and aid in understanding the system constraints.

11. Quality of Service (QoS)

Quality of Service (QoS) refers to the reliability of data flows in a network. QoS provides different priority levels to data flows and an assurance that data loss will be reduced or prevented. Networks with limited bandwidth and critical systems may rely on higher QoS levels for increased reliability. Critical data is given priority over less important data using QoS protocols. As critical flows increase, data flow queue

management tools limit lower priority data flows to ensure that higher priority data is transmitted with greater reliability. QoS tools are intended to improve reliability of data flows within a network, but they do not solve bandwidth problems in highly congested networks. The Navy's IWS have many components with critical data flows and will require QoS tools to prioritize network traffic.

12. Phased Transition

An organization should develop detailed plans using an architecture evaluation method prior to implementation of a complete SOA. Rather than attempting to transition an enterprise from legacy systems to a complete SOA all at once, incremental implementation is recommended. Architectural evaluations will mitigate risks for each planned increment and alleviate potential re-work. Incremental implementation also allows an organization time to adjust to changes and provides an environment fostering adaptation and acceptance as personnel become more familiar with new systems. Users may have difficultly adapting to entirely new systems and may resist an SOA if they are not given time to understand the new systems. To mitigate change management risks, a phased transition is recommended (Erl, 2008a, p. 87).

13. Governance

Governance refers to the application of processes utilized throughout an organization when developing an SOA. These processes govern how SOAs are designed, developed, implemented, and maintained, which ensures conformity to the guiding architectural principles and regulations established by the organization. "Governance represents the responsibility of administering, maintaining, and evolving what is delivered by SOA projects" (Erl, 2008b, p. 97).

14. ROI

As stated earlier in this chapter, there are differing viewpoints on how to calculate return on investment (ROI) for SOA. Experts argue the feasibility of calculating ROI for SOA.

> What makes calculating the ROI of SOA even more challenging is that architecture, by itself, doesn't offer specific features that companies can readily identify with some particular return. After all, architecture is an investment that companies must make well in advance of any return, and must continue to make over the lifetime of their SOA implementations. (Schmelzer, 2005)

> Some experts believe ROI for SOA does not provide a true measure of benefits since the calculated ROI is based upon components that make up the system and these measures do not capture the benefits of the entire solution. SOA is a set of best practices, a philosophy, and a drive toward business transformation. SOA, for the most part, is intangible, with long-term results to the business. (McKendrick, 2007)

> The larger issue is that SOA, at the end of the day, is a systemic change in the way organizations approach enterprise architecture. Thus, the benefits will only be understood when the architecture has undergone that change. (Linthicum, 2007)

Although some experts do not believe there is real value in calculating ROI of an SOA, others believe it is required and are using innovative methods to calculate ROI for SOA. "Some measure of ROI is nearly always used as a justification for major technology investments within large enterprises" (Gabhart, 2007, p. 1). Gabhart divides SOA ROI calculations into three quantifiable benefits of SOA: "Tactical ROI as a result of standards-based service oriented integration, Operational ROI based on service and process reuse, and Strategic ROI due to business and technology agility" (p. 2).

Tactical ROI focuses on reducing redundancy and other initial cost reductions to provide justification for initiating an SOA. The four steps listed below describe the method for calculating tactical ROI.

- Compute the savings realized due to reduced middleware licensing costs.
- Compute the savings afforded due to reduced development time.
- Project savings due to reduced maintenance costs.
- Add the results of steps 1-3 together and fold that into whatever ROI formula your organization uses (i.e. net gain divided by investment). (Gabhart, 2007, p. 2)

As previously stated, tactical ROI is just an initial figure for SOA justification. Operational and strategic ROI must be analyzed to provide more accurate estimations of an SOA's value.

Operational ROI provides information for "the short to medium time frame," by analyzing the re-use of services. Two methods for calculating operational ROI for SOA are the iterative re-use model and the calculated re-use model. When using the iterative re-use model, the "investment return is measured based on the number of times a service or process is reused rather than an arbitrary time frame" (Gabhart, 2007, p. 3). Development of reusable components may initially cost much greater than non-reusable components, but the cost savings are realized upon each successive re-use of a given service. The calculated re-use model is a "mathematical model [that] computes SOA value based upon a few key variables such as number of services available for reuse, degree of reuse, and service complexity" (p. 3). This method requires an organization to compare current non-SOA development component costs to those that are developed for re-use in an SOA.

Strategic ROI should be calculated to provide a complete analysis of the long-term benefits gained by implementing an SOA.

> Strategic ROI is manifested though cost controls, risk mitigation, and new revenue generation as a result of agility…Strategic ROI is the ultimate expression of what SOA is all about. It's about making a strategic investment in an agile enterprise infrastructure and at the same time aligning the business and technology sides of the organization to work toward common, shared objectives. (Gabhart, 2007, p. 4)

Listed below are guidelines for calculating strategic ROI. It is important to understand that strategic ROI is more an art than a science.

- System development and maintenance costs saved due to the ability to modify information systems with little to no coding required (simply modify or rearrange the orchestration of several services).
- Estimated legal costs and fines avoided due to faster and more reliable responsiveness to regulatory changes.
- Revenue generated via the rapid creation of new services as well as the manipulation and reconfiguration of existing ones.

- Revenue generated due to ability to expose internal capabilities as consumable services by business partners and clients (this potentially generates completely new streams of income). (Gabhart, 2007, p. 4)

Calculating ROI for an SOA is not a concept that gains consensus from all SOA experts, but as more organizations migrate to SOA, methods for ROI calculation are emerging. Gabhart's method is only one recommendation for calculating the ROI for an SOA. Employing Gabhart's method provides guidelines for initial ROI estimates as well as medium to long term ROI estimates. In the future, managers are not likely to proceed with any IT endeavor that lacks measures for providing a return on investment.

15. SOA Benefits

Silo-based systems make architectural evolution difficult due to multiple systems with independent architectures that are not compatible. The Navy currently acquires systems vertically (as separate acquisition processes). Service-orientation solves the evolution issues, since systems can be developed horizontally across many acquisition programs. Once horizontal development begins, all programs utilizing an SOA can begin development using a common framework and components, consequently, reducing design time, implementation time, and overall cost reduction.

Service-orientation attempts to solve past problems by designing for the concepts listed below (Erl, 2008a, p. 81).

- Increased consistency in how functionality and data is represented
- Reduced dependencies between units of solution logic
- Reduced awareness of underlying solution logic design and implementation detail
- Increased opportunities to use a piece of solution logic for multiple purposes
- Increased opportunities to combine units of solution logic into different configurations
- Increased behavioral predictability
- Increased availability and scalability
- Increased awareness of available solution logic

16. SOA Challenges

Some challenges that SOA systems face are outlined below (Erl, 2008a, p. 85):

- Increased performance requirements: As multiple systems reuse a single service, system performance needs to increase to keep up with demand and prevent latency issues. Performance measures will need to be developed for each service based on intended usage.
- Reliability due to concurrent usage: A service may exhibit reduced reliability as more than one system is requiring that service's functions at the same time. Controls to mitigate the risk of reduced reliability must be introduced for critical systems.
- Single point failure: As an increasing number of systems rely on one service for a particular function or process, failure of the service will impact every system relying upon that service. Governance may aid in mitigating this risk. Backup systems are not ideal, but should be considered for high-risk processes.
- Increased demand on hosting environments: As demand on hosting environments increases, runtimes may become excessive and lead to excessive latency issues. Hosting environments will need to be scalable to mitigate increased demand. Concurrent requests from multiple applications must be addressed to reduce latency issues as a service processes these requests.
- Service contract versioning issues and redundant service contracts: Service contracts address how services will interface with various applications and describe their desired functionality. Versioning must be standardized to avoid confusion and redundant operations that may lead to increased runtime. Proper governance will reduce the likelihood of versioning issues and redundant service contracts.

B. OPEN ARCHITECTURE (OA)

This section defines Open Architecture (OA), introduces and defines Naval Open Architecture (NOA), outlines the NOA strategy and business model, and discusses how the Navy assesses the "openness" of its programs.

1. Definition

The concepts of open architecture (OA) have been around for years. Simply put, OA is an architecture that employs open standards for key interfaces within a system.

What this means is that the components of a system or a system-of-systems are easily interchangeable, simply plug and play. OA principles encompass both the business processes and technical practices that enable modular, interoperable systems that adhere to open standards. These principles apply to both the construction of a system and the management of its lifecycle. The fundamental drivers of OA are to reduce total ownership costs and time to deliver a system. The goals of OA are to

- Increase Reuse
- Increase Flexibility
- Faster Time to Market
- Reduce Costs
- Leverage Competition
- Improve Interoperability
- Reduce Risk (Nelson, 2007, p. 8)

OA principles are intended to support these goals and fundamental drivers by identifying the key business processes and technical practices that aid in the construction and deployment of OA systems.

2. Naval Open Architecture (NOA)

In the commercial environment, new technologies have driven the market to adapt to a modular open systems approach to developing new systems. This same environment has also affected the acquisition of National Security Systems (NSS) across the DoD. The Navy, having realized the impacts and opportunities associated with open architecture, has implemented its own open architecture policy. Naval Open Architecture (NOA) is an enterprise-wide, multi-faceted business and technical strategy for acquiring and maintaining NSS as interoperable systems that adopt and exploit open system design principles and architectures (PEO-IWS, 2007).

The NOA website defines its open architecture as “a Navy initiative for a multi-faceted strategy providing a framework for developing joint interoperable systems that adapt and exploit open-system design principles and architectures” (DAU, 2006, p. 13). This framework includes a set of principles, processes, and best practices that:

- Provide more opportunities for competition and innovation
- Rapidly field affordable, interoperable systems
- Minimize total ownership cost
- Optimize total system performance
- Yield systems that are easily developed and upgradeable
- Achieve component software reuse (p. 13)

3. NOA Strategy

In order to help implement its open architecture framework, the Navy has developed an overarching NOA strategy. This strategy includes a vision statement, principles, goals and supporting objectives. The NOA vision is to "transform our organization and culture and align our resources to adopt and institutionalize open architecture principles and processes throughout the naval community in order to deliver more warfighting capabilities to counter current and future threats" (PEO-IWS, 2007, p. 1).

In order to achieve the NOA vision, five underlying principles have been identified. These five principles are:

> 1. Encourage competition and collaboration through the development of alternative solutions and sources.
>
> 2. Build modular designs and disclose data to permit evolutionary designs, technology insertion, competitive innovation, and alternative competitive approaches from multiple qualified sources.
>
> 3. Build interoperable joint warfighting applications and ensure secure information exchange using common services (e.g., common time reference), common warfighting applications (e.g., track manager) and information assurance as intrinsic design elements.
>
> 4. Identify or develop reusable application software selected through open competition of "best of breed" candidates, reviewed by subject-matter-expert peers and based on data-driven analysis and experimentation to meet operational requirements.

5. Ensure lifecycle affordability including system design, development, delivery, and support while mitigating Commercial off-the-Shelf (COTS) obsolescence by exploiting the Rapid Capability Insertion Process/Advanced Processor Build methodology. (PEO-IWS, 2007, p. 2)

In order to adhere to these five principles, the Navy has established several goals and supporting objectives. While the following goals define the direction for the Navy's software architectures, the supporting objectives strengthen each goal by describing how they will be accomplished. The goals and their supporting objectives are outlined below.

Goal 1:

Change Naval processes and business practices to utilize open systems architectures in order to rapidly field affordable, interoperable systems.

Supporting Objectives:

1. Provide and refine policies, guidance and definitions required to establish a common approach for Naval OA.

2. Support OPNAV in coordinating budget guidance across combat system and C4ISR communities, exploiting synergies across existing programs of record, to support Naval Power 21 priorities.

3. Assist the Milestone Decision Authority, Program Manager, and Resource Sponsor in assessing program openness, where appropriate, to make informed OA investment decisions.

4. Implement and refine OA Contract Guidance for use in applicable procurements tailored as necessary to meet domain-specific requirements.

5. Facilitate cross-domain component reuse to reduce costs and enable more effective technology insertion. (PEO-IWS, 2007, pp. 2-3)

Goal 2:

Provide Naval OA systems engineering leadership to field common, interoperable capabilities more rapidly at reduced costs.

Supporting Objectives:

1. Conduct Naval OA systems engineering experimentation to facilitate the fielding of interoperable capabilities and encourage collaboration.

2. Oversee Naval OA implementation efforts ensuring standardized and disciplined processes are utilized across domains.

3. Identify and foster "quick win" candidates and near-term proofs of concept for OPNAV to field additional capabilities at reduced costs.

4. Ensure the Naval OA process remains relevant to S&T advancement.

5. Work with the Test & Evaluation (T&E) community, academia, and industry partners to identify opportunities for reducing T&E expenses as a result of OA. (PEO-IWS, 2007, pp. 2-3)

Goal 3:

Change Navy and Marine Corps Cultures to Institutionalize OA Principles.

Supporting Objectives:

1. Increase awareness of Naval OA through the development of standard communication tools (i.e. presentations, papers, web content).

2. Increase workforce skill sets through targeted training and ongoing research.

3. Conduct Outreach to External Stakeholders to increase the awareness of the Naval OA initiative. (PEO-IWS, 2007, pp. 2-3)

4. Open Architecture Enterprise Teams (OAET)

To implement the Naval OA strategy, Navy leadership established a Naval Open Architecture Enterprise Team (OAET). The Program Executive Officer Integrated Warfare Systems (PEO-IWS) was assigned overall responsibility and authority for directing the NOA effort and was designated as the OAET lead. Representatives from

AIR, SURFACE, SUBS, SPACE, C4I and Marine Corps domains are incorporated into the OAET to ensure that NOA principles, guidelines, business practices, and technical solutions are utilized across the enterprise and within each domain. The OAET is responsible for developing an overarching OA acquisition and business strategy (Young, 2004, August 5).

5. NOA Business Model

The Navy has developed an OA business model to help guide the acquisition process. The Navy's OA business model focuses on several key principles, including the utilization of performance specifications; specialization at the module or component level; defining roles and responsibilities for component delivery, system integration and lifecycle support; and the criticality of a "spiral" or "build test build" process (DAU, 2006, p. 3). Figure 3 illustrates the Navy's OA business model.

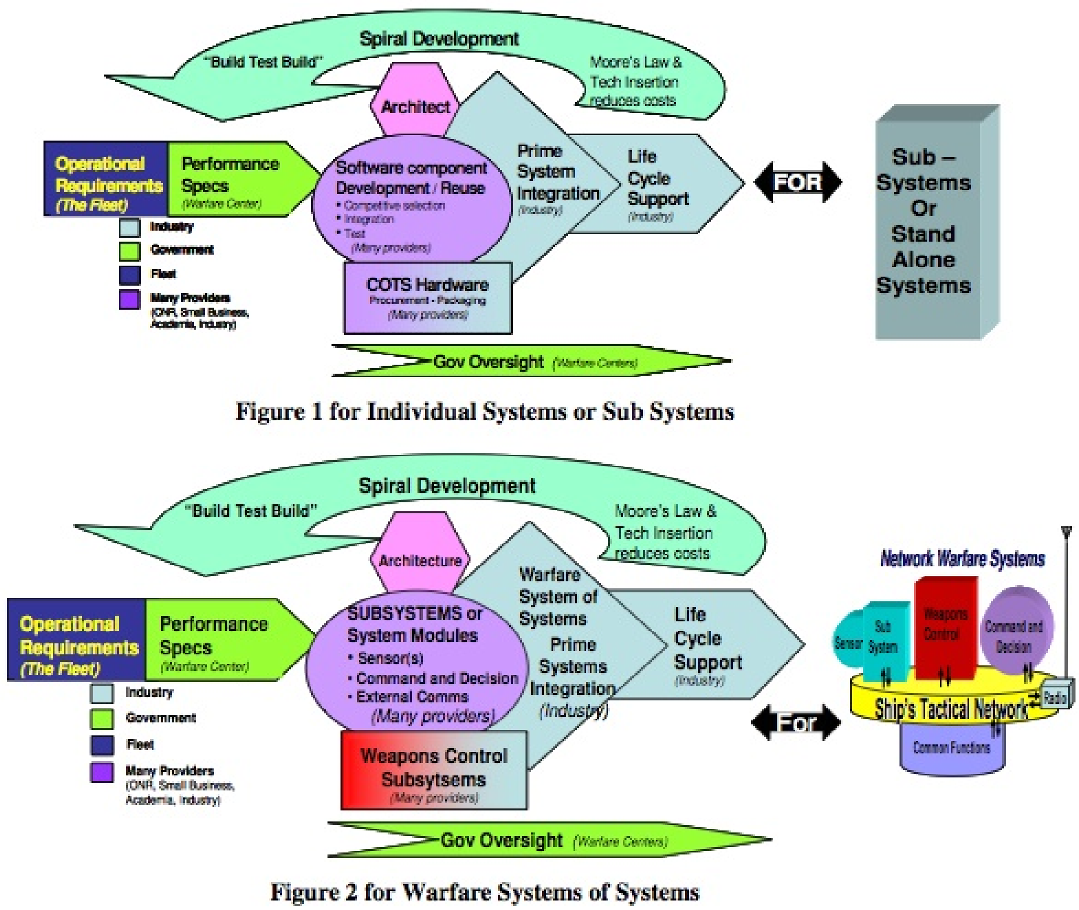

Figure 3. OA Business Model from (DAU, 2006, p. 2)

6. NOA Tools

The OAET has developed an assessment model and an assessment tool to help program managers evaluate the "openness" of their respective program or system. The Open Architecture Assessment Model (OAAM) is a descriptor of the openness of a program or system. The OAAM was developed to provide program managers a means of describing the openness of their program or system. Program managers accomplish this by assessing their respective program or system and determining the "as-is" level of openness and the desired "to-be" level of openness. The OAAM provides a macro-level evaluation of the program or system and is not meant to provide improvements but rather to uncover alternatives for creating more openness.

The Open Architecture Assessment Tool (OAAT) provides two functions: 1) a descriptive measure of a program's or system's level of OA maturity and 2) a means by which a program manager can determine where his or her program stands with regards to what is possible (Shannon, 2006, October 19). The OAAT is an analytical tool that assesses the openness of a program or system based on business and technical interrelated questions. The OAAT implements the OAAM as a descriptor and provides a reproducible and more consistent method of evaluating a program or system.

Employing the OAAM and OAAT is a continuous process that identifies a program's or system's current state of openness, desired state of openness, and the alternatives to progress from the current state to the desired state. As alternatives are examined, a business case is developed to determine the progression toward the desired state of openness. The OAAM and OAAT should be used during all phases of the acquisition process in order to continually assess and facilitate the OA maturity of a program or system.

C. SOA AND OA RELATIONSHIP

The previous sections discussed the background of SOA and OA. This section will discuss the relationship between SOA and OA.

An SOA can be built using proprietary means; however, this type of SOA would not take full advantage of the strategic goals and benefits of utilizing an SOA. Therefore, to fulfill the SOA vision, an SOA should focus on exploiting open standards and OA principles.

1. Strategic Goals and Benefits of SOA

There are several strategic goals and benefits associated with an SOA. The strategic goals of an SOA are:

- Increased Intrinsic Interoperability
- Increased Federation
- Increased Vendor Diversity Options
- Increased Business and Technology Alignment (Erl, 2008b, p. 12)

The strategic goals of an SOA lead to the attainment of the strategic benefits, which are:

- Increased ROI
- Reduced IT Burden
- Increased Organizational Agility (p. 12)

The strategic goals and benefits of an SOA are long-term goals and are intended to improve the IT environment throughout the entire enterprise. These long-term strategic goals contrast the previously used tactical goals of traditional "stove-piped" applications that focused on meeting short-term requirements.

2. Applying Open Standards and OA Principles

Employing open standards and applying OA principles to an SOA promote the strategic goals and benefits of the SOA. Applying OA principles increases the flexibility of software applications by utilizing standard interfaces that increase the interoperability of different systems. Open standards promote vendor diversification by abstracting proprietary implementation details, which allows vendors to easily integrate system components. As new technologies are developed, open standards and OA principles permit interfaces that are technologically neutral, which allows systems to be easily upgradeable and interchangeable.

D. SUMMARY

This chapter defined important terms, concepts and principles, and defined the relationship between SOA and OA. Services-Orientated Architecture and design is a relatively new and emerging paradigm that increases system interoperability. Experts' definitions vary on what and how an SOA is designed and implemented, but most agree on core concepts. SOA increases interoperability across multiple systems that previously had very centralized processes. IWS can benefit from SOA as common services are used across multiple platforms. Reuse is another benefit SOA aspires to provide. As service re-use increases, IWS will be modified more easily and ROI will increase as redundant applications are replaced by composable service structures. SOA provides the benefit of

incremental implementation that reduces integration issues and allows organizations to adapt to an SOA over time. Challenges exist when implementing an SOA, but with proper planning and architectural evaluations many risks are mitigated.

The Navy currently follows the DoD guidance requiring exploration of OA software systems. To further OA use within Naval systems, the Navy should begin to combine the use of OA with other emerging technologies such as SOA and services-oriented computing. The next chapter will examine the current Defense Acquisition System in order to help answer the first thesis question.

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III. DEFENSE ACQUISITION SYSTEM

A. INTRODUCTION

The previous chapter provided some background information on the basic principles and concepts behind Services-oriented Architectures (SOA) and Open Architectures (OA), defined the relationship between them, and discussed some of the benefits of incorporating SOA and OA into IWS. This chapter will focus on the current Defense Acquisition System and will provide an explanation of how to incorporate SOA and OA into the acquisition process in order to provide an answer to the first thesis question: “Does the Defense Acquisition System need to be altered to take advantage of SOA and OA implementation into the acquisition lifecycle?”

Within the Defense Acquisition System, there are three major decision-support systems utilized by defense leaders to enable proper decision-making concerning the acquisition of National Security Systems. These decision support systems include the Joint Capabilities Integration and Development System (JCIDS); the Defense Acquisition System; and the Planning, Programming, Budgeting and Execution System (PPBE). The incorporation of SOA and OA into IWS impacts each of these three decision support systems. The focal point of this chapter will be the impacts of SOA and OA within the Defense Acquisition System decision support process and the acquisition lifecycle. Although this research will focus on the Defense Acquisition System and the acquisition lifecycle, the paper will also touch on a few impacts SOA and OA may have within the JCIDS process. Additionally, the Naval Open Architecture (NOA) policy guidance and its application to help develop SOA policy guidance will be discussed, as well as other factors affecting SOA and OA.

B. DODD 5000.1

The *DoDD 5000.1* is a directive that applies to all acquisition programs in the Department of Defense. The directive’s purpose is to provide management principles, mandatory policies, and procedures to managers for all current and future acquisition

programs. This directive provides definitions for the Defense Acquisition System, an Acquisition Program, the Defense Acquisition Executive (DAE), the Milestone Decision Authority (MDA), and the Program Manager (PM). The directive sets the policy and is the basic guidance required for all DoD acquisition programs.

1. Policy

The Defense Acquisition System is a complex and multi-faceted system utilized by the Department of Defense (DoD) in the acquisition of its National Security Systems. The purpose of the Defense Acquisition System is best described in the following quote.

> The Defense Acquisition System exists to manage the nation's investments in technologies, programs, and product support necessary to achieve the National Security Strategy and support the United States Armed Forces. The investment strategy of the Department of Defense shall be postured to support not only today's force, but also the next force, and future forces beyond that. (Under Secretary of Defense (AT&L), 2003a, p. 3)

The Defense Acquisition System is governed by five fundamental policies: flexibility, responsiveness, innovation, discipline, and streamlined and effective management. Acquisition programs for SOA and OA are based upon principles that meet the requirements of these five governing policies. The following paragraphs will describe how SOA and OA support the five fundamental policies set forth in the *DoDD 5000.1*.

a. Flexibility

SOA and OA systems, once established in an organization, provide flexibility through increased agility and potential re-use opportunities. As these systems mature, they increase flexibility, allowing the systems to adapt quickly to time-sensitive needs.

b. Responsiveness

SOA and OA provide the necessary responsiveness for deploying systems to the warfighter in the "shortest time practicable." As stated previously, SOA should be

incorporated incrementally and will require considerable time to fully mature. Responsiveness will improve as SOA and OA systems mature.

c. Innovation

The DoD requires MDAs and PMs to explore innovative technologies to reduce cycle-times and costs. SOA and OA are proven innovative technologies in the commercial market and are gaining acceptance in the DoD. OA is intended to reduce costs and development times. The Navy has already realized the need to migrate to OA systems. SOA is intended to increase interoperability and reduce redundant systems and components, therefore reducing future cost and cycle-time associated with DoD networks.

d. Discipline

SOA and OA systems require the same level of discipline that is required of any acquisition program–the difference is in the baseline parameters. Since these technologies are relatively new, standard baseline parameters and exit criteria will need to be developed over time as data is gathered on programs using these technologies.

e. Streamlined and Effective Management

Streamlined and effective management can mitigate risks as each program is documented to produce credible cost, schedule, and performance parameters. Managers must be flexible, as these technologies will require multiple MDAs and PMs to mutually support programs across system and program boundaries.

2. Modular Open Systems Approach (MOSA)

The DoD recognizes the performance and total ownership cost advantages that a modular open-systems approach (MOSA) provides. "A modular, open-systems approach shall be employed, where feasible" (Under Secretary of Defense (AT&L), 2003a, p. 9). MOSA is defined as "an integrated business and technical strategy that employs a modular design and, where appropriate, defines key interfaces using widely supported,

consensus based standards that are published and maintained by a recognized industry standards organization" (OSJTF, 2004, p. 6). MOSA is considered a key enabler to evolutionary acquisition and supports many principles that are consistent with SOAs. Combining a MOSA with an SOA may reinforce the objectives presented in the OSJTF guide (2004). As seen in Figure 4, the principles and benefits that OSJTF states as being enabled by MOSA are also supported when using an SOA.

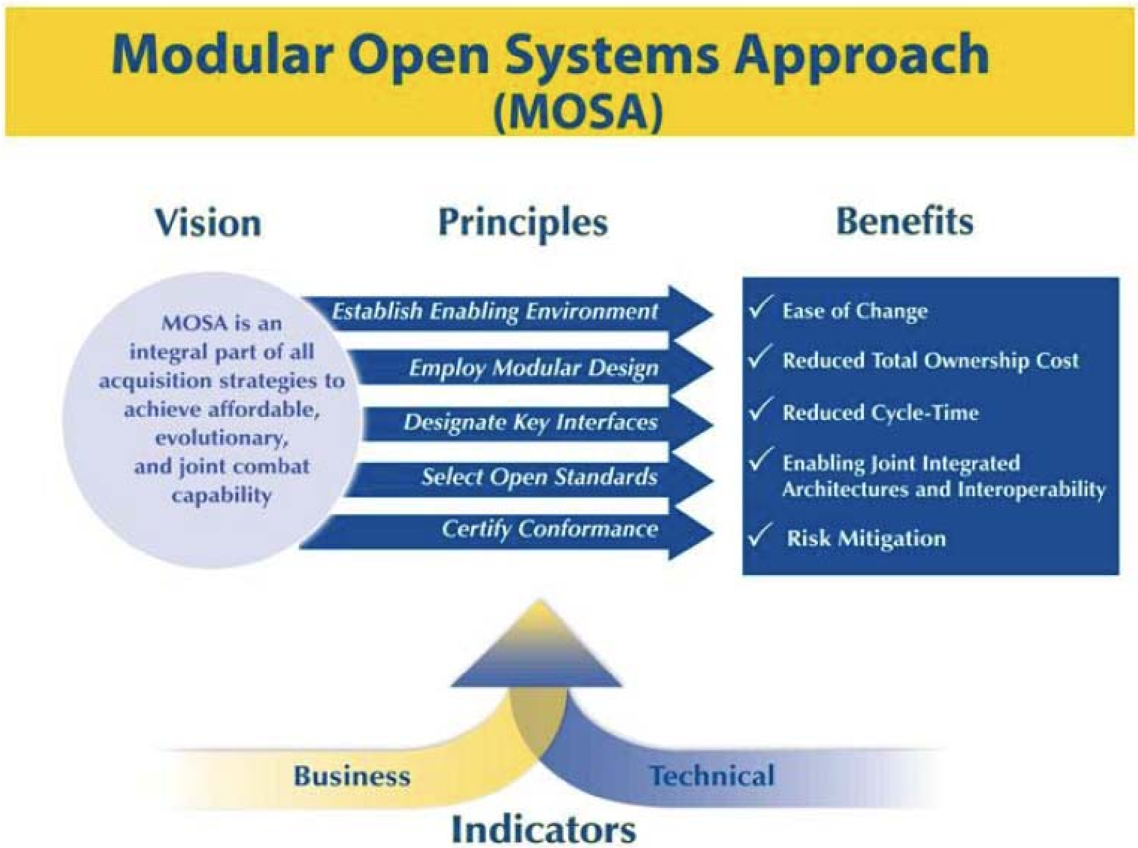

Figure 4. Modular Open Systems Approach from (OSJTF, 2004, p. 3)

The guidance in the *DoDD 5000.1* and the OSJTF guide mandate the use of open-systems architectures and support concepts integral to SOA. Instead of inhibiting SOA use, these documents enable SOA through the requirements established for using MOSA. OA and SOA are approaches that optimize total system performance and minimize total ownership costs.

The *DoDD 5000.1* is the primary directive that must be followed by all acquisition programs. The *DoDD 5000.2* is the instruction for the operation of the Defense Acquisition System and is discussed in the next section.

C. DODI 5000.2

The *DoDI 5000.2* is the instruction for the operation of the Defense Acquisition System. This instruction establishes an acquisition management framework; creates a framework for developing technology opportunities; sets the requirement for using integrated architectures; and describes evolutionary acquisition as the preferred DoD strategy for rapid acquisition programs. This section will focus on the acquisition management framework, integrated architectures, evolutionary acquisition, and technology opportunities for the DoD acquisition programs.

1. Defense Acquisition Management Framework

The *DoDI 5000.2* provides a "simplified and flexible management framework for translating mission needs and technology opportunities, based on approved mission needs and requirements, into stable, affordable, and well-managed acquisition programs that include weapon systems and automated information systems (AISs)" (Under Secretary of Defense (AT&L), 2003b, p. 1). The framework, provided by *DoDI 5000.2*, "authorizes Milestone Decision Authorities (MDAs) to tailor procedures to achieve cost, schedule, and performance goals" (p. 1).   The flexibility of the acquisition management framework outlined in the *DoDI 5000.2* and the ability to tailor it to the needs of the program is a key enabler for incorporating SOA and OA into IWS. The development processes of SOAs and OAs differ greatly from those of legacy systems and must be tailored to capture the objectives of the enterprise. Aligning an SOA or OA with the objectives of the enterprise necessitates flexibility within the acquisition management framework. Figure 5 illustrates the defense acquisition management framework established by the *DoDI 5000.2*.

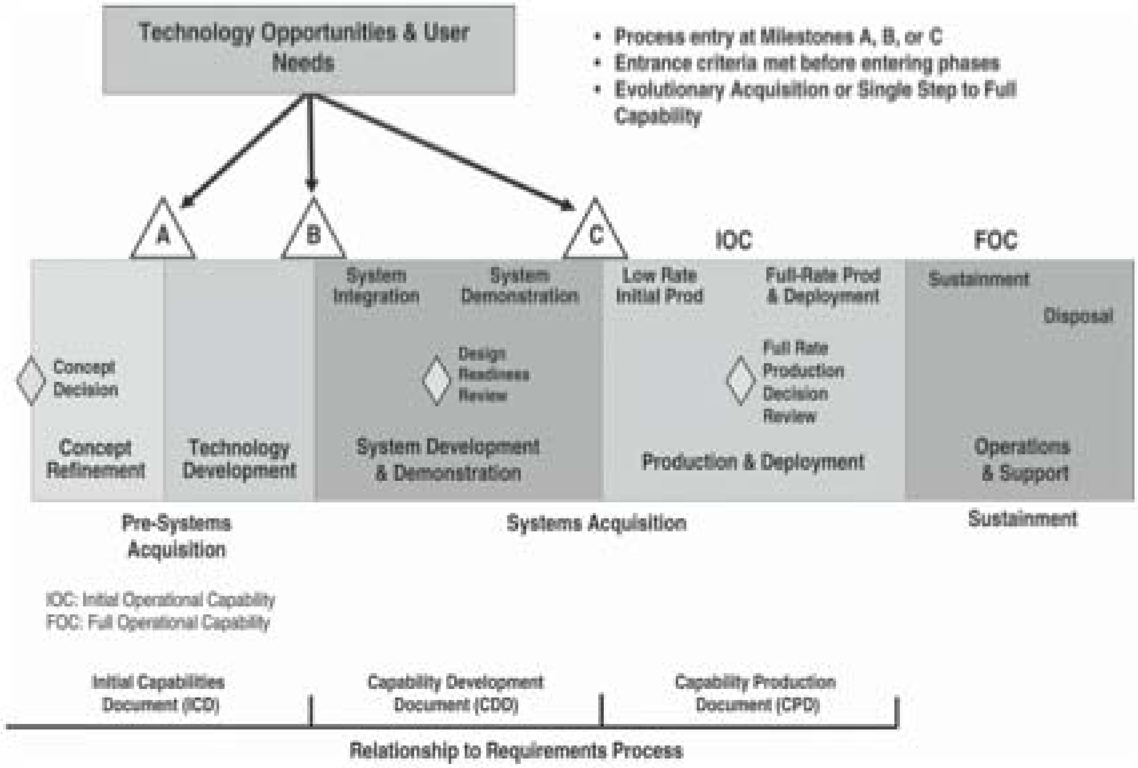

Figure 5. Defense Acquisition Management Framework from (DAU, 2005, p. 49)

Although the defense acquisition management framework was designed to help manage the acquisition of complex weapons systems rather than services (as defined in Chapter II), the basic management precepts can still be applied to SOA. The primary service delivery lifecycle stages when implementing an SOA are services-oriented analysis, service modeling, services-oriented design, service development, and service implementation (Erl, 2008b, p. 77). The acquisition of services can follow the basic outline of the defense acquisition management framework. The services-oriented analysis and modeling phases can be incorporated into the concept refinement phase; whereas, the services-oriented design phase fits into the technology development phase. Similarly, the service development phase fits within the system development and demonstration phase, and the service implementation phase fits within the production and deployment phase. Once the service or services enter the operations and support phase, service governance phases take over. The concept decision, milestone reviews, design readiness review, and full-rate production decision review can similarly be applied to an

SOA as it progresses through the service delivery lifecycle stages. The service delivery lifecycle stages of an SOA do not completely fit within the defense acquisitions management framework; however, the flexibility of the framework allows MDAs and Program Managers to tailor these procedures and processes to meet the needs of implementing an SOA.

In February 2008, the Secretary of the Navy, Donald C. Winter, released a notice outlining improvements for the Navy's requirements and acquisition process. The purpose of this document is

> To establish a review process to improve governance and insight into the development, establishment, and execution of acquisition programs in the Department of the Navy (DON). The goal of the review process is to ensure alignment between Service-generated capability requirements and acquisition, as well as improving senior leadership decision-making through better understanding of risks and costs throughout a program's entire development cycle. (Winter, 2008, p. 2)

The new process integrates a two-pass system with three gate reviews per pass into the acquisition lifecycle. The notice outlines the procedures for each pass and its associated review gates and establishes input and exit criteria for each gate, as well as the briefing content for each gate. The new process also establishes the System Design Specification (SDS) Development Plan, which is developed either during the Concept Refinement Phase or Technology Development Phase, depending on the milestone at which the program is initiated. The notice also establishes gate review membership, which includes a Chair, Principal Members and Advisory Members. The process flow is outlined for programs that are initiated at either Milestone A or Milestone B, as seen in Figures 6 and 7.

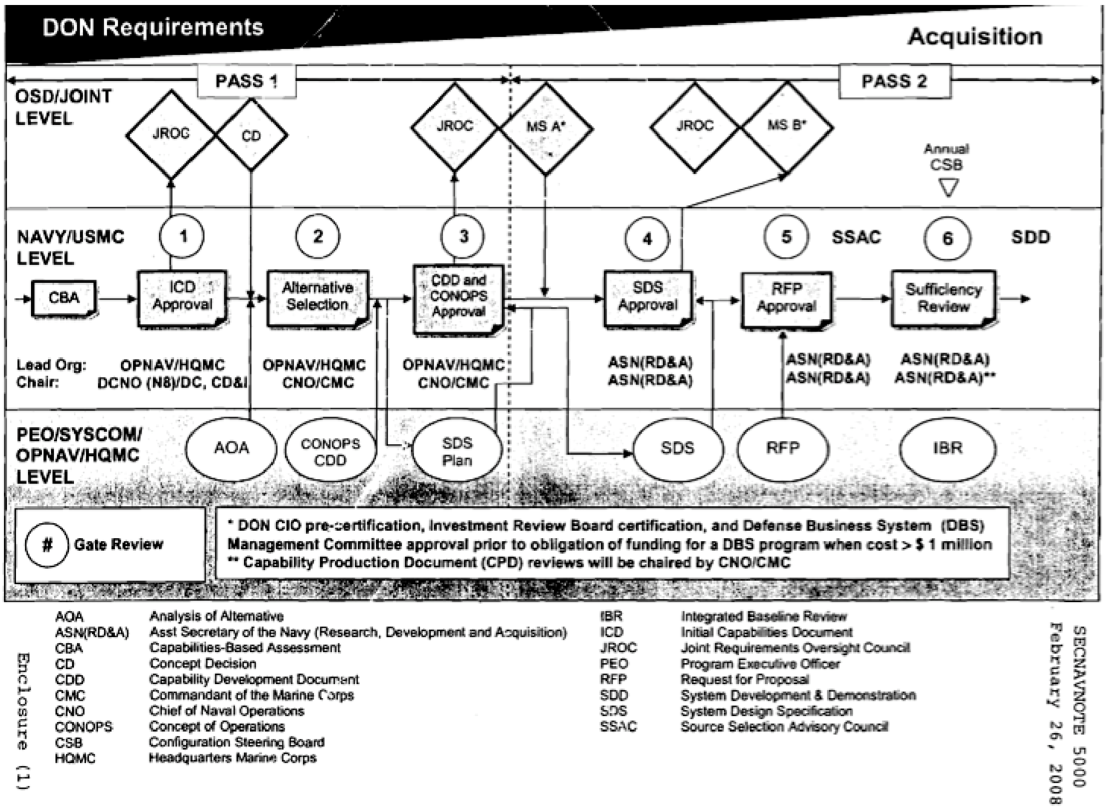

Figure 6. DON Requirements/Acquisition Two-Pass/Six-Gate Process with Development of a System Design Specification (illustrated example for program initiation at Milestone A) from (Winter, 2008, p. 9)

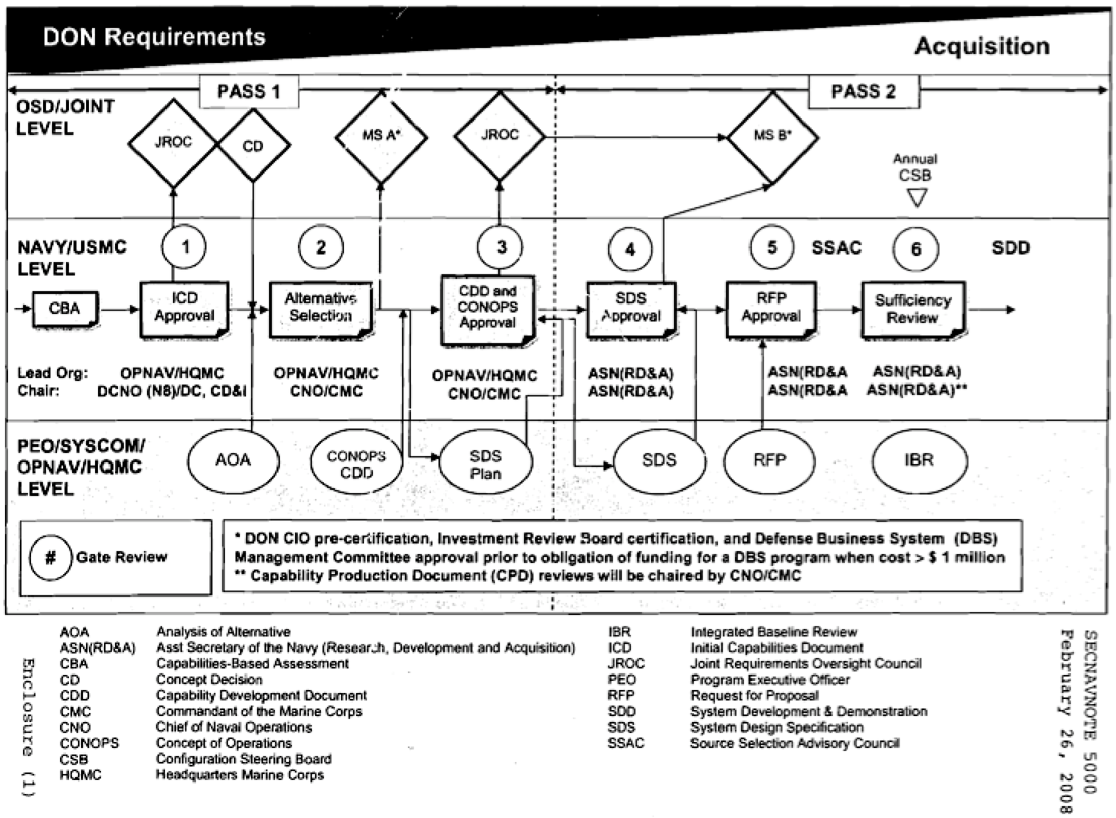

Figure 7. DON Requirements/Acquisition Two-Pass/Six-Gate Process with Development of a System Design Specification (illustrated example for program initiation at Milestone B) from (Winter, 2008, p. 10)

As seen in Figures 6 and 7, this new process adds more decision reviews into a process that already has six. While the addition of these new decision review gates are meant to "establish a disciplined and integrated process" to be "implemented in an integrated, collaborative environment," the amount of time and effort managing this decision review process becomes increasingly time-consuming and complex. The main purpose behind the defense acquisition management framework established in the *DoDI 5000.2* is to provide a simple and flexible management process. The addition of these new review passes and gates is contrary to the concepts of the defense acquisition management framework. The addition of the SDS Development Plan also adds time and complexity. The development of the SDS duplicates many of the requirements that are already covered in the Initial Capabilities Document (ICD) and the Capability

Development Document (CDD). Adding more review processes and documentation requirements will not be conducive to fielding systems that respond rapidly to changes in requirements and technology advances.

2. Integrated Architectures

The *DoDI 5000.2* requires all "DoD components to develop joint integrated architectures for capability areas as agreed by the Joint Staff" (Under Secretary of Defense (AT&L), 2003b, p. 3). IWS that use SOA and OA fall under the requirement for development as joint integrated architectures. These systems must be interoperable with the Global Information Grid (GIG) architecture and must be developed in accordance with the Joint Technical Architecture. The Navy must address impacts of using systems that take advantage of SOA and OA and determine the impact they have on the GIG and other joint systems. Interoperability is not only required within new systems the Navy develops, it is also imperative that new systems continue to enhance joint capabilities. During requirements and capabilities development, each military department and the related defense agencies are required to participate to ensure new systems enhance interoperability.

3. Evolutionary Acquisition

"Evolutionary acquisition is the preferred DoD strategy for rapid acquisition of mature technology for the user" (Under Secretary of Defense (AT&L), 2003b, p. 4). This acquisition method is intended for mature technologies that have proven benefits that can be quickly applied to improve military capabilities. Evolutionary acquisition relies upon updating requirements continuously to develop the most useful systems for users. Figure 8 depicts the evolutionary acquisition strategy. This figure illustrates program initiation and the process through the evolutionary acquisition cycle. Feedback loops provide updated requirements and refine concepts as the program continues toward completion.

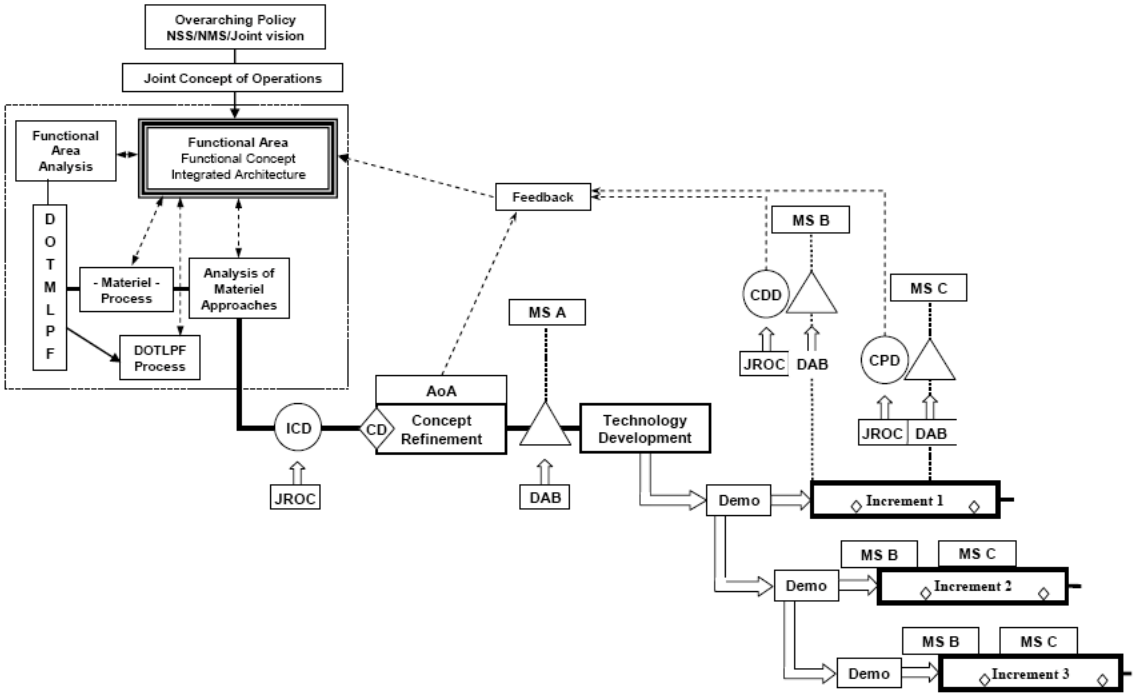

Figure 8. Requirements and the Acquisition Process from (Under Secretary of Defense (AT&L), 2003b, p. 4)

There are two approaches to evolutionary acquisition, and a program may elect to use either. These approaches are spiral development and incremental development.

a. *Spiral Development*

Spiral development is the preferred development method for DoD acquisition programs.

> In this process, a desired capability is identified, but the end-state requirements are not known a program initiation. Those requirements are refined through demonstration and risk management; there is continuous user feedback; and each increment provides the user the best possible capability. The requirements for future increments depend on feedback from users and technology maturation. (Under Secretary of Defense (AT&L), 2003b, p. 4)

b. Incremental Development

Although incremental development is not the preferred acquisition method, it is acceptable to use for programs that are not conducive to spiral development. "In this process, a desired capability is identified, an end-state is known, and that requirement is met over time by developing several increments, each dependent on available mature technology" (Under Secretary of Defense (AT&L), 2003b, p. 5).

c. Combined Development

SOA and OA are relatively new technologies within the DoD. To properly employ and mitigate risks with early SOA and OA development and implementation into Navy programs, both spiral and incremental development should be considered. Some requirements for IWS are well known and are unlikely to change in the near future; these programs would benefit from more traditional incremental development methods. As IWS systems mature to address emerging and future threats, many requirements are unknown and known requirements are likely to change to adapt to these threats; these systems will benefit better from spiral development.

SOA is a prime candidate for systems requiring innovative technology in a highly dynamic environment. SOA provides the agility to rapidly adapt systems as requirements are updated and new requirements are realized. OA enhances SOA's ability to adapt more rapidly due to OA's alleviation of proprietary hardware and software.

4. Technology Opportunities

Rapid advances in technology and, more specifically, in software and network architectures provide opportunities for the Navy to enhance and expand IWS capabilities. SOA and OA are relatively new technological concepts that will allow Navy IWS to adapt rapidly as new requirements emerge. Interoperable systems requiring modifications will continue to expand as technology allows for improved networking.

The *DoDI 5000.2* requires technologists and industry to seek new technology opportunities to facilitate future capabilities. SOA and OA are two opportunities to improve future capabilities. Developing an SOA does not require using open architectures and Navy IWS will benefit from using SOA alone. Using "an open, or at least elegant, architecture is key to forming a basis for independent modular variety: and through design specification and configuration management accountability is essential for managing the complexity of multiple product releases" (Dillard & Ford, 2007, p. 494). In case studies by Dillard and Ford, the advantages of using OA as the basis for architectures shows significant reduction in product cycle-time when using incremental or spiral development. OA complements SOA by improving modularity and reducing vendor specific product requirements. During spiral development, requirements are continuously updated to better meet user needs. Using OA to develop SOAs may provide the flexibility for more rapid changes to requirements during spiral or incremental development. Composable systems can reap the benefits of OA and SOA since these technologies provide the modularity for interoperability across multiple platforms.

5. Summary

The *DoDD 5000.1* and *DoDI 5000.2* include the guidelines for developing and acquiring emerging technologies such as SOA and OA. The DoD has realized the need for systems that meet needs of multiple platforms and that are capable of adapting to meet new threats. Reducing product cycle-times is imperative and Naval IT programs can no longer remain in a 3- to 5-year development cycle. Once established, OA and SOA will provide the foundation for more rapid modifications. These technologies will also lead to reduced costs, as composable systems become common in Navy IWS. The current acquisition system presently mandates OA to be considered when developing new systems. SOA provides the technology opportunities and capabilities that the directives and instructions require managers to consider. For example, much of the current effort in the surface domain is to transition the major combat systems to OA and to use the components to provide the basis for the new (CGX) combat system (Benedict, 2008, p. 2).

D. JOINT CAPABILITIES INTEGRATION AND DEVELOPMENT SYSTEM

As stated previously in the introduction to this chapter, SOA and OA have impacts within the Defense Acquisition System, JCIDS, and PPBE decision support systems. This section will highlight some of the impacts that SOA and OA may have on the JCIDS process.

The JCIDS process "involves an analysis of Doctrine, Organization, Training, Material, Leadership and Education, Personnel and Facilities (DOTMLPF) in an integrated, collaborative process to define gaps in warfighting capabilities and propose solutions" (DAU, 2005, p. 39). As the DoD continually gravitates towards more joint warfighting capabilities, the "gaps" between legacy systems become more and more apparent. The lack of interoperability between legacy systems acquired through traditional "stove-piped" acquisition processes requires defense leadership to examine and analyze solutions that promote increased interoperability through the JCIDS process. The implementation of SOA and OA into future combat systems through the JCIDS process enables increased interoperability and promotes joint warfighting concepts. The JCIDS link to the Defense Acquisition System, as seen in Figure 9, provides the required analysis of the interoperability and integrated architectures of a defense acquisition program as it progresses through its acquisition lifecycle. The JCIDS process provides a top-down approach to determining essential warfighting capabilities. The top-down approach incorporates meaningful levels of analysis across the enterprise. To implement an SOA, a top-down approach is needed to emphasize the relationship between the business processes of the enterprise and the services that represent and implement the business logic (Erl, 2008b, p. 78).

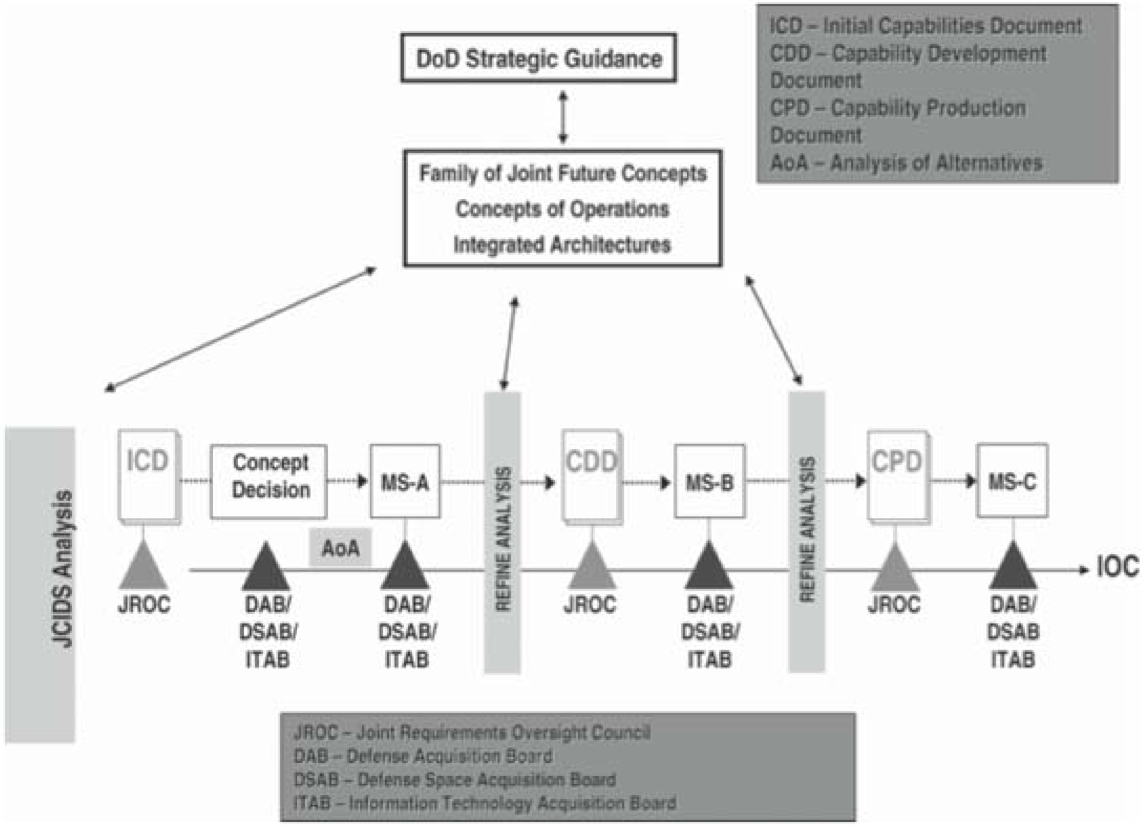

Figure 9. JCIDS Link to Defense Acquisition from (DAU, 2005, p. 41)

During the JCIDS process, the Initial Capabilities Document (ICD) is developed and "provides the definition of the capability need and where it fits in the broader concepts and architectures" (DAU, 2005, p. 40). Again, the ICD provides the top-down analysis approach needed to ensure that the services-orientation is applied to the required capabilities of the enterprise. The Capabilities Development Document (CDD) and the Capability Production Document (CPD) provide the Key Performance Parameters (KPP), which are the "attributes or performance characteristics considered most essential for an effective military capability" (p. 40). The utilization of SOA and OA should be reflected in the KPPs.

E. CONTRACTING PROCESS

Rendon's Naval Postgraduate School research, *Using A Modular Open Systems Approach in Defense Acquisitions: Implications for the Contracting Process*, explored the use of the modular open systems approach (MOSA) as a method for implementing an evolutionary acquisition strategy and the implications it had on the contracting process (2006, p. 1). As stated earlier in this chapter, a MOSA supports many principles and benefits that are consistent with SOAs and OAs; therefore, Rendon's assertions of the implications of a MOSA on the contracting process can be applied to SOA and OA. In his research, Rendon states:

> The program acquisition strategy should describe agency needs and objectives using mission-related or performance-based terms. In addition, the contracting strategy should flow from the acquisition strategy, and both should be consistent in goals and objectives. An acquisition strategy using a modular open systems approach should be focused on critical areas such as adopting evolving requirements, promoting technology transfer, facilitating system integration, leveraging commercial investment, reducing cycle-time and lifecycle cost, ensuring interoperability, enhancing commonality and reuse, enhancing access to cutting edge technologies and products from multiple suppliers, mitigating technology obsolescence risk, mitigating single source of supply risk, enhancing lifecycle supportability, and increasing competition. (Rendon, 2006, p. 29)

Similar to using a MOSA contracting strategy, the contracting strategy supporting an SOA- or OA-based acquisition strategy should be structured to achieve these MOSA objectives, which are consistent with many of the SOA and OA objectives.

Rendon's research further shows that "the solicitation for an acquisition program using an open systems approach will require specific language unique to the use of a modular open systems approach. Thus, the procurement documents that make up the solicitation should incorporate the specific language that reflects the preference or mandated use of a modular open systems approach in the acquisition program" (Rendon, 2006, p. 36). Similar to a MOSA approach, solicitation for an acquisition using an SOA- or OA-based approach will require specific language that is unique to the use of SOA or

OA. Additionally, the procurement documents will require specific language that reflects the use of an SOA- or OA-based approach in the acquisition program.

Rendon's research also states that "in acquisition programs using a modular open systems approach, the government will want to incentivize the contractor to meet higher levels of "openness" in the design and development of the system" (2006, p. 57). For programs that intend to implement SOA and OA, program managers and contracting officers will need to develop an acquisition strategy and a contracting strategy that provides incentives to contractors to utilize SOA and OA principles and practices to achieve the high levels of "openness" desired for future IWS.

Having realized the importance of the contracting process when acquiring and fielding systems that incorporate OA, the PEO-IWS developed an OA contracting guidebook for program managers. The Naval Open Architecture Contract Guidebook was developed to "provide Program Managers, Contracting Officers, and their supporting organizations with guidance and example contract language to assist them in incorporating Open Architecture principles into their contracts" (PEO-IWS 7, 2007, p. 1). Similarly, the Navy will need to develop a contracting guidebook for implementing SOA to provide program managers and contracting officers guidance for incorporating SOA principles into their contracts.

F. NOA AND SOA POLICY GUIDANCE

The purpose of this section is to review the current NOA policy guidance and to review how the Navy is developing its SOA guidance. As stated in the previous chapter, in the OA section, the NOA policy guidance is set forth in several DoD and Navy policy documents. In January 2006, CAPT James J. Shannon, Naval Open Architecture Program Manager, PEO-IWS 7.0, developed a brief delineating what program managers need to know about NOA. In that brief, he highlighted the major documents that help establish NOA policy guidance. The *DoDD 5000.1* and the use of Modular Open Systems Approach (MOSA) were discussed earlier in this chapter. The following sections will cover the remaining policy guidance concerning NOA, adapted from Shannon's brief.

1. NOA Scope and Responsibilities

The August 5, 2004, Assistant Secretary of the Navy (Research, Development & Acquisition) Policy Statement, entitled *Naval Open Architecture Scope and Responsibilities*, assigns responsibility and authority for directing the NOA effort to the Program Executive Officer (PEO) Integrated Warfare Systems (IWS) and establishes the OA Enterprise Team (OAET), which is to be chartered and led by PEO-IWS. It further states that the "OAET shall be responsible to defining an overarching OA acquisition strategy and develop guidance addressing incentives, intellectual property issues, contracting strategies and funding alternatives" (as cited in Shannon, 2006, January, p. 6). It also states that the OAET "shall prepare, staff, and promulgate a Navy-wide OA business strategy" (p. 6). Additional OAET roles and responsibilities outlined in the ASN(RD&A)'s memo are below:

- Lead the Navy Enterprise to OA implementation
- Provide OA Systems Engineering leadership to PEO's, industry partners, Joint Organizations, Navy Warfare Centers and other participating organizations
- Provide the forum and process by which cross domain OA proposals and solutions are utilized across domains
- Identify cross-domain components and opportunities for cost reduction and reuse
- Leverage technical, business, and organizational solutions from all participating communities
- Establish an advisory team, comprised of industry and academia, to interpret and advise the team on an as periodic basis (p. 7)

2. Memorandum of Understanding

The December 3, 2004, Memorandum of Understanding (MOU) among PEO-IWS, PEO SUBS, PEO (T), PEO C4I, and PEO Space Systems made the OAET responsible for the OA effort across the Naval Enterprise, including ensuring implementation conforms to MOSA policy and requirements, ensuring that OA progress assessments comply with the Program Assessment Review Tool (PART), and promoting NOA Enterprise products to OSD, DoD agencies and other Service components (as cited

in Shannon, 2006, January, p. 8). The MOU is under revision at present, and will expand the participation to include additional PEOs, OPNAV codes and SYSCOM technical authorities (Wessman, 2008).

3. OA EXCOMM Action Items

The 15 May 2005 ASN(RD&A) Memorandum summarizing OA EXCOMM III of February 22, 2005, required ACAT I programs to use the OA Assessment Model (OAAM) to determine the "as-is" level of openness and desired "to-be" state and to produce metrics and conduct business case analyses if necessary (as cited in Shannon, 2006, January, p. 11). As stated in the previous chapter in the OA section, the OA assessment model and an assessment tool were developed to help program managers evaluate the "openness" of their respective program or system.

4. OPNAV Requirements

The December 23, 2005, Deputy Chief of Naval Operations (Warfare Requirements and Program) (N6/N7) Requirement for Open Architecture (OA) Implementation "established the requirement to implement Open Architecture (OA) principles across the Navy Enterprise" (as cited in Shannon, 2006, January, p. 15). It also established the OA Council (OAC) of representatives of N6/N7 Division Directors to work with the OAET on the requirements set forth in the ASN(RD&A)'s August 5, 2004 Memorandum. The letter also directs the OAC, PEO-IWS 7.0, and the OAET to focus assessment priorities in support of the following capabilities: track management, combat identification (CID), data fusion, time-critical targeting and strike, and integrated fire control (p. 15).

5. NOA Policy and Guidance Summary

Over the last several years, the Navy has spent considerable time and effort developing its NOA policies and guidance to best implement open architecture into acquisition strategies. The policies discussed previously have set the foundation the Navy needs to successfully implement OA. The Navy has also developed guidance

documents to help program managers implement OA into their respective programs, which includes the *NOA Contract Guidebook*. The Navy has also developed the NOA website that contains all the information concerning NOA. In short, the Navy's policies and guidance concerning OA have begun to catch up with the commercial market and should facilitate the implementation of OA into future combat systems acquisition processes.

6. SOA Policy and Guidance

In April 2006, the Navy's Chief Information Office (CIO) chartered the Department of Navy (DON) SOA Transformation Group (Wennergren, 2006). The DON SOA Transformation Group

> will provide the direction for Commands to align to a DON Net-Centric, interoperable environment, based on a Service-Oriented Architecture ensuring all services are visible, trusted, accessible and usable–when needed and where needed–to accelerate the decision cycle process throughout the DON WarFighter community, via web-centric technology. (Wennergren, 2006, p. 1)

Similar to the OAET, the DON SOA Transformation Group is responsible for developing a DON SOA policy, a DON SOA Concept of Operations (CONOPS), metrics, and Return on Investment (ROI) models. They will also be responsible for developing white papers that will include best practices for implementing SOA, acquisition strategy recommendations for implementing SOA and certification and accreditation policies (p. 2).

Although the DON SOA Transformation Group has yet to deliver any official policies or guidance concerning the implementation strategy the Navy will utilize with regards to SOA, the ball is at least rolling in the right direction. The Navy's promotion of SOA, along with its policies and guidance for implementing OA, are beginning to prepare the Navy for new business and technology trends that will impact the acquisition of future combat systems.

G. OTHER FACTORS

1. Horizontal Systems Engineering

In December 2004, The Assistant Secretary of the Navy, John J. Young, Jr., released a memorandum stating the need for cross-platform commonality with engineering systems. The current vertical management of acquisition programs complicates cross-platform commonality, since decisions are delegated to prime contractors. The prime contractors limit system modularity by optimizing "their particular business models rather than ours" (Young, 2004, December 23, p. 1). Young recognizes the need for Executive Committees (EXCOMM) to promote cross-platform commonality by developing "action paths" that lead to horizontal systems integration across multiple platforms. "The product of these EXCOMMs will be recommendations and action assignments for my signature to develop architectures, roadmaps and implementation plans to increase commonality" (p. 1). The result of the recommendations will lead to enterprise-wide commonality in hardware and software.

SOA combined with OA provides the mechanisms for initiating horizontal integration for IWS through hardware and software based on OAs and SOAs. OA mitigates risks associated with prime contractors utilizing proprietary software and hardware to optimize their business models and creates flexibility for the Navy when integrating systems across multiple platforms. SOA allows for increased modularity and interoperability in IWS that require common capabilities but have varying mission requirements. SOA combined with OA supports horizontal systems engineering and provides a path for the transition from a vertical acquisition to horizontal acquisition process.

2. PEO-IWS

The PEO-IWS vision states: "PEO IWS leads a professional and experienced organization that delivers Enterprise solutions for Naval warfare systems that operate seamlessly and effectively within the Fleet and Joint Force" (Department of the Navy, 2008). The PEO-IWS is intended to facilitate the transformation of the acquisition

process from the current vertical process to a more horizontal process. Jesse M. Mink's Naval Postgraduate School thesis, *Analysis of Horizontal Integration within the Program Executive Office, Integrated Warfare Systems*, suggests barriers exist that prevents PEO-IWS from facilitating its mission. The following excerpt from Mink's thesis states the PEO-IWS function.

> PEO IWS was founded to oversee design, construction, and maintenance of all surface ship and submarine combat systems. The stated intent of this re-organization was to shift from a platform-centered approach to a more integrated consistent approach across all combat systems. PEO IWS is the entity charged with coordinating the integration of warfare systems into a single, functioning system of systems that can then be integrated onto any platform. Integration of the warfare system and the ship itself requires harmonization and communication between and across PEO IWS and its stakeholders. (Mink, 2006, p. 22)

Although the PEO-IWS plays an integral part when deciding what new IWS should be developed for the Navy's ships, the funding is distributed to other PEOs such as PEO Carriers or PEO Ships. This funding structure does not provide the flexibility necessary for PEO-IWS to horizontally integrate common systems into various platforms. Distributing the funding for IWS directly to PEO-IWS would alleviate the problems with disparately acquired systems that reduce interoperability. Providing interoperable systems by managing common systems acquisition programs from a single PEO can lead to more rapid acquisition, increased interoperability, and cost reductions. The PEO-IWS must not only be involved in the acquisition process for IWS but must also be responsible for maintenance actions that require system changes. Managing IWS for all ships will reduce interoperability issues arising from changes to one platform and the effects the changes will have on other platforms. As SOA- and OA-based IWS are horizontally integrated on naval platforms, system modifications overseen by PEO-IWS will provide rapid systems changes and ensure the systems remain interoperable to enhance warfighter capabilities.

3. Information Technology Portfolio Management

In October 2005, the Acting Deputy Secretary of Defense, Gordon England, issued a DoD Directive that "establishes policy and assigns responsibility for the

management of DoD information technology (IT) investments as portfolios that focus on improving DoD capabilities and mission outcomes" (Assistant Secretary of Defense (NII/DoD CIO), 2005, p. 1). The policy further states that "IT investments shall be managed as portfolios to: ensure IT investments support the Department's vision, mission, and goals; ensure efficient and effective delivery of capabilities to the warfighter; and maximize return on investment to the Enterprise" (Assistant Secretary of Defense (NII/DoD CIO), 2005, p. 2).

In the article "Best practices for Building SOA Applications," seven steps to SOA adoption are identified. One of the key steps to effective SOA adoption is to create a portfolio of services (SYS-CON Media Inc., 2008, p. 2). As stated before, an SOA models the business or enterprise as a collection of self-contained services, which are implementations of a well-defined piece of business functionality. In the DoD, a well-defined piece of business functionality can be viewed as a capability. DoD Instruction 8115.02 states "managing portfolios of capabilities aligns IT with the overall needs of the warfighter, as well as the intelligence and business activities which support the warfighter" (Assistant Secretary of Defense (NII/DoD CIO), 2006, p. 3). By implementing an SOA, the DoD can better manage its IT investments as a portfolio of services that implement well-defined pieces of business functionality (capabilities) that support the Enterprise's vision, mission and goals while ensuring efficient and effective delivery of capabilities to the warfighter.

DoDI 8115.02 also states that IT portfolio management

> is a key enabler of information sharing. In accordance with DoD Directive 8320.2 (Reference (m)), portfolio management enables data sharing across Components, supports cross-Component communities of interest, and ensures data sharing agreements are implemented by the respective Components. These activities should maximize return on investment for the enterprise by reusing accessible data rather than recreating existing data. (Assistant Secretary of Defense (NII/DoD CIO), 2006, p. 5)

One of the key tenets of an SOA is re-use. By managing an SOA as a portfolio of services, different components within the Enterprise can leverage services developed by

other components, alleviating redundant capabilities while maximizing return on investment for the entire Enterprise. Utilization of an SOA within the Navy and the rest of the DoD will help facilitate the management of IT investments as portfolios.

H. SUMMARY

This chapter discussed the current Defense Acquisition System, analyzed how SOA and OA can be integrated into the current processes and addressed the current NOA policies and the Navy's future roadmap for SOA policies. It also discussed other factors affecting the implementation of SOA and OA, with regards to Horizontal Systems Engineering, the current PEO-IWS structure and IT portfolio management. The main focus of this chapter was to answer the first thesis question: "Does the Defense Acquisition System need to be altered to take advantage of SOA and OA implementation into the acquisition lifecycle?"

IV. CASE STUDY

A. INTRODUCTION

The previous chapter discussed the impacts of SOA and OA within the Defense Acquisition System. The focus of this chapter is to analyze the Navy's SOA implementation within the Consolidated Afloat Networks and Enterprise Services (CANES). The first section gives a broad overview of CANES and what it is trying to accomplish. The next section will discusses how the Navy plans to implement SOA within CANES and how it adheres to SOA and OA principles and practices. The following section will discuss how CANES will utilize SOA and OA to provide future IWS capabilities. This chapter and this case study will provide answers to the second and third thesis questions, "Do current Navy OA policies and SOA practices provide the necessary interoperability requirements for future IWS?" and "What benefits might SOA and OA provide to IWS?"

B. CANES OVERVIEW

Currently, there are a multitude of legacy standalone afloat networks throughout the Navy. These legacy standalone systems were developed and fielded by multiple acquisition programs and program offices throughout the Navy. These legacy network systems represent the "stove-piped" acquisition strategies of the past. In order to move forward and eliminate these "stove-pipes," the Navy implemented CANES as an integrated approach to consolidate and reduce the number of afloat networks. Figure 10 depicts how CANES intends to consolidate the legacy afloat networks.

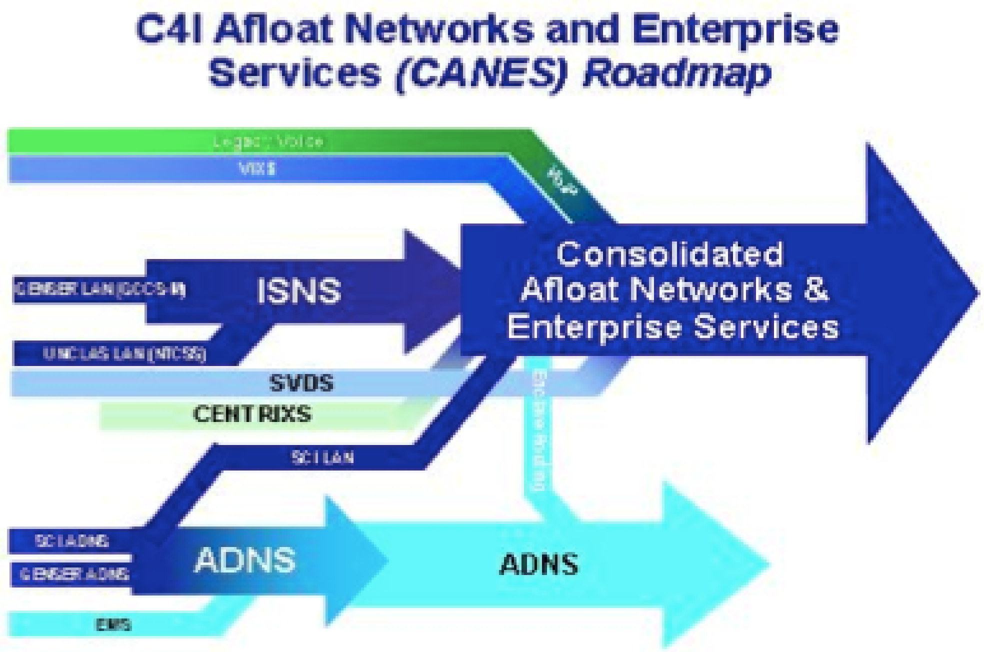

Figure 10. CANES Roadmap from (SPAWAR, 2007a, p. 2)

The Navy's vision for CANES was developed based on "an overarching concept to reduce the number of afloat networks, providing efficiency through a single engineering focus on technical solutions" (SPAWAR, 2007a, p. 1). This reduction of networks "allows for streamlining acquisition, contracting, and test events, and efficiencies in the reduction of multiple Configuration Management (CM) baselines, logistics and training "tails" into a unified support structure" (p. 1). In order to achieve this, the CANES vision established four equally important goals

> **Goal 1–**Collapse the number of networks in the current N6 afloat network portfolio by use of cross-domain technologies.
>
> **Goal 2–**Reduce the infrastructure footprint and associated costs for hardware afloat.

> **Goal 3**–Provide capability to meet current and projected warfighter requirements.
>
> **Goal 4**–Extend network consolidation goals to naval programs outside the current N6 afloat network portfolio. (p. 1)

These goals demonstrate the Navy's desire to eliminate the "stove-piped" acquisition processes of the past. Consolidating these legacy networks allows the Navy to reduce infrastructure and provide increased capabilities while lowering lifecycle costs. In order to integrate the legacy network systems, the CANES program will implement an infrastructure that supports a Services-oriented Architecture (SOA).

C. ADHERENCE TO SOA AND OA PRINCIPLES AND PRACTICES

CANES development is predicated upon adhering to common SOA and OA principles and practices. SOA and OA principles and practices were described previously in Chapter II. The focus of the second thesis question is current Navy OA policies and SOA practices. This section will analyze the principles and practices CANES is following and determine if this program is adhering to common SOA and OA practices.

A significant CANES goal is to utilize SOA and OA to breakdown the current "stove-pipes" and replace the current network structure with a more interoperable and adaptable solution. Figure 11 illustrates a high-level depiction of the current network that must be transformed to incorporate an SOA.

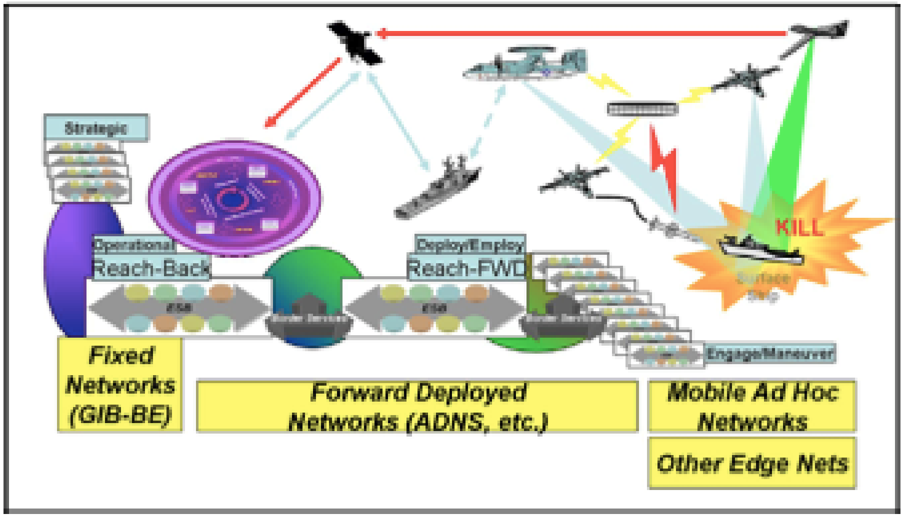

Figure 11. Exchange of Information Across Multiple Secure Naval Networks from (SPAWAR, 2007b, p. 4).

1. CANES RFI

The Space and Naval Warfare Systems Command (SPAWAR), the Program Executive Office–Command, Control, Communications, Computers, Intelligence (PEO-C4I), Networks, Information Assurance (IA), and Enterprise Services Programs Office (PMW 160) distributed a Request for Information (RFI) to obtain information for possible development of the CANES system. Within the RFI, the aforementioned organizations list five CANES key objectives

- Increased network reliability and efficiency
- Interoperable, distributable, and loosely coupled
- A tiered model of service interactions
- Improved control over costs
- A scalable tiered model of service interactions (SPAWAR, 2007b, p. 4)

Interoperability is an increasing concern with naval networks. The Navy's future IWS systems must be interoperable and reliable. Interoperability is the biggest benefit SOA provides. SOA aims to reduce interoperability issues and therefore increase system reliability among naval platforms. The CANES system is based on SOA and OA

principles that promote interoperability. The CANES system development process has realized SOA, based on open standards, can provide the solution to increase interoperability among naval platforms.

The loose coupling within the CANES system is one of the key tenets of an SOA. Loose coupling is an SOA design goal to reduce the dependency between services, while still providing interoperability within a system. Although loose coupling is desired in an SOA, interoperability has greater importance. Services should only have reduced dependency to a degree that still allows interoperability between multiple services and across multiple applications.

Transitioning to a more horizontal acquisition structure will provide improved control over costs. An incremental approach should be adopted when implementing an SOA. CANES is planned as an incremental implementation beginning with core services and incorporating new services as needed. As common systems are implemented across varying platforms, costs should be reduced.

The Navy requires that CANES is scalable. SOA is intended to provide scalability by reducing duplicative service implementations. Current systems will be replaced with systems that utilize interoperable core services. A tiered model of service interactions will standardize the CANES system by using common interfaces. "By adhering to standardized interfaces, systems can utilize common services which will reduce the cost and consolidate the maintenance of the systems" (SPAWAR, 2007b, p.5).

"Two main tenets of CANES enterprise service architecture are: 1) an adherence to standards, and (2) technology/vendor neutrality" (SPAWAR, 2007b, p. 7). Navy OA policies and practices promote the development of interoperable and reusable applications through common standards and interfaces, which leads to open competition and technology neutrality.

The CANES RFI is a positive step towards developing an SOA utilizing OA practices and principles.

2. CANES SOA Reference Architecture

To properly implement an SOA, CANES is using the OASIS SOA reference model. The OASIS model "is an abstract framework for understanding significant entities and relationships between them within a service-oriented environment, and for the development of consistent standards or specifications supporting that environment" (MacKenzie et al., 2006, p. 1). This model provides the necessary framework to develop an SOA and provides an abstract reference model that can be applied to SOA regardless of technology implementation. The OASIS reference model for SOA's relationship to other system work is depicted in Figure 12.

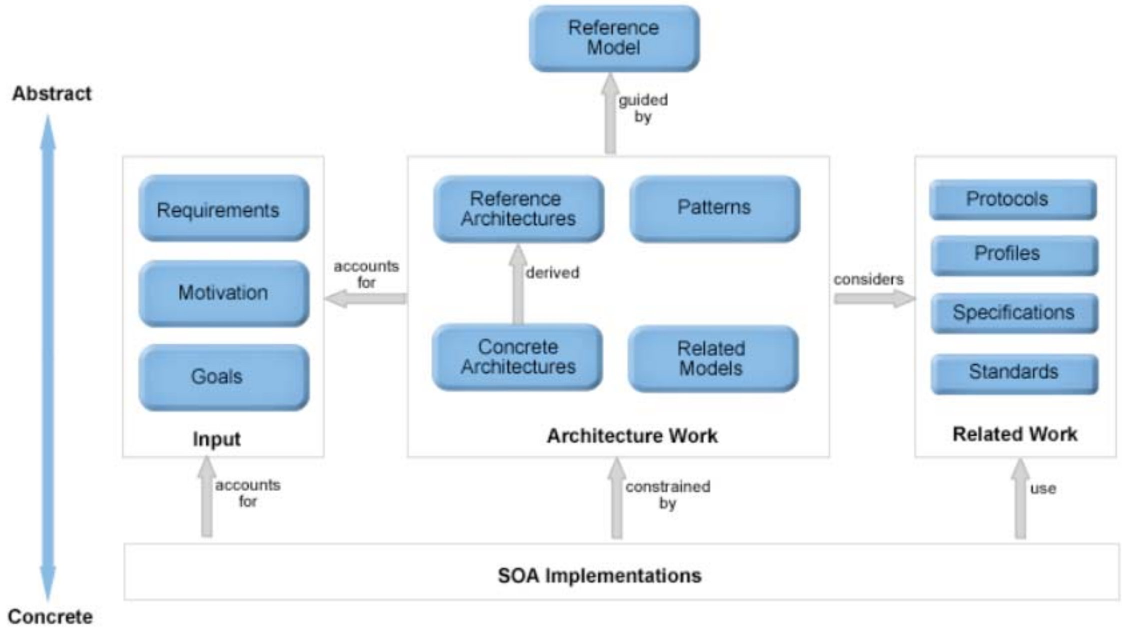

Figure 12. How the Reference Model Relates to Other Work from (MacKenzie et al., 2006, p. 5)

Utilizing the OASIS reference model provides CANES the flexibility to adapt to emerging needs for various platforms. Using the OASIS reference model is an example of how the Navy is following industry standards for accepted SOA practices.

> The Reference Model (RM) of current interest is an abstract framework for understanding significant entities and relationships between them within a service-oriented environment, and for the development of consistent standards or specifications supporting that environment. It is

> based on unifying concepts of SOA and may be used by architects developing specific service-oriented architectures or in training and explaining the SOA paradigm. A reference model is not directly tied to any standards, technologies or other concrete implementation details (such as "Web Services"). Hence, a good reference model provides common semantics that can be used unambiguously across and between different implementations. (Nickull, 2006)

The CANES SOA reference architecture identifies several qualities that must be addressed in the implementation of the CANES services infrastructure. The qualities addressed by the CANES SOA reference architecture are

- Interoperability
- Quality of Service
- Loose Coupling
- Service Operations Management
- Service Lifecycle Management
- Service Metadata Management
- SOA Governance (MITRE Corporation, 2007, p. 3-1)

Chapter II of this thesis outlined several of the basic SOA concepts and principles. The qualities outlined in the CANES SOA reference architecture mirror those concepts and principles.

An SOA based on common services provides seamless interaction with new and legacy systems regardless of platform specific characteristics. "The CANES Services Infrastructure must integrate disparate application environments" (MITRE Corporation, 2007, p. 3-1). By using common services and interfaces, legacy systems can become encapsulated enabling communication between disparate environments, which increases interoperability.

The CANES Services Infrastructure "must ensure the delivery of acceptable levels of service in terms of security, performance, and integrity" (MITRE Corporation, 2007, p. 3-1). An SOA must provide different priority levels to data flows that provide the security and integrity of the data while maintaining the necessary flow of critical data.

An SOA design goal is to reduce the dependency between services while still providing interoperability within a system through loosely coupled services. The CANES SOA reference architecture identifies the importance of loose coupling as "a core SOA design principle that ensures flexibility, reusability, and resiliency in the face of dynamic systems" (MITRE Corporation, 2007, p. 3-2).

The CANES SOA reference architecture identifies the necessity to provide Service Operations Management, Service Lifecycle Management, and Service Metadata Management. When implementing an SOA, services are defined and designed as a piece of business functionality. Similar to a business, an SOA must provide the operations and lifecycle management of the business or service functionality. Since the metadata of a service describes the different aspects of the service and its capabilities, it to must be managed as a business functionality.

Governance refers to the application of processes utilized throughout an organization when developing an SOA. These processes govern how SOAs are designed, developed, implemented and maintained, which ensures conformity to the guiding architectural principles and regulations established by the organization. The CANES SOA reference architecture states that governance policies "should be defined that dictate or provide guidance for service creation, service testing, service utilization, service management, and service versioning" (MITRE Corporation, 2007, p. 3-6). These governance policies will help ensure that CANES utilizes SOA principles, processes and best practices throughout its development.

D. CANES SOA AND OA USE TO PROVIDE FUTURE IWS CAPABILITY

The benefits that SOA and OA provide to IWS are the focus of the third thesis question. This section will identify some of the benefits of CANES and how its development can help provide future IWS capabilities.

1. Joint Interoperability

While CANES is a Navy system that is being developed for ships, it must not only be interoperable with other shipboard network system, it must also be interoperable

with joint systems. The Army, Air Force, and the Marine Corps are developing SOA-based systems. The Navy is collaborating with the other services, using a Multi-service SOA consortium (Figure 13), to ensure standard interfaces and specifications are utilized to meet joint interoperability requirements.

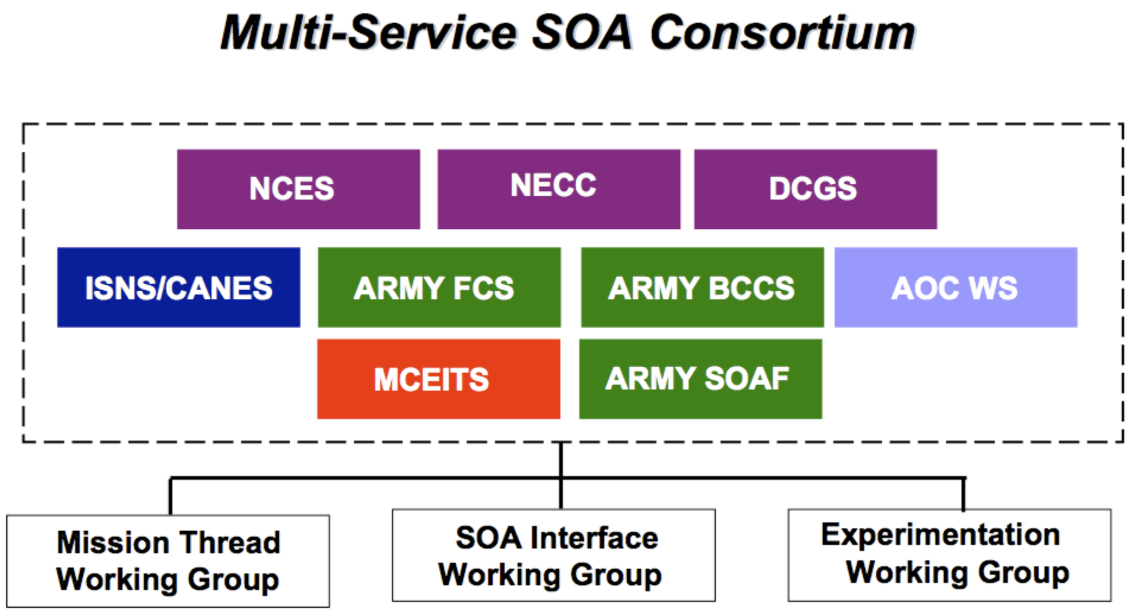

Figure 13. Multi-Service SOA Consortium from (PEO-C4I, 2008, p. 26)

As each military service develops SOA- and OA-based systems, it is critical that common standards are used. Figure 14 depicts the interaction of each military service's SOA interactions. "A DoD/DNI Enterprise Services Technical Governance Forum is validating a set of common standards, specifications, and reference implementations to enable joint interoperability across a multi-Service/Agency SOA" (PEO-C4I, 2008, p. 28). As each military service's particular SOA program matures, governance is increasingly important. A governance organization should be independent from any particular military component to autonomously monitor changes within each military service's SOA in order to mitigate risks associated with interoperability. This organization should continue to provide guidance throughout the lifecycle of all military SOA systems.

Figure 14. Multiple SOA Initiatives Being Developed for Each Military Service from (PEO-C4I, 2008, p. 22)

CANES is taking positive steps toward successful joint interoperability by participating in the Multi-Service SOA Consortium collaboration effort to develop common standards that will provide the necessary measures for joint interoperability. Increasing the success of joint interoperability is the goal of the Enterprise Services Technical Governance Forum. Figure 15 is a diagram of the forum's basic structure.

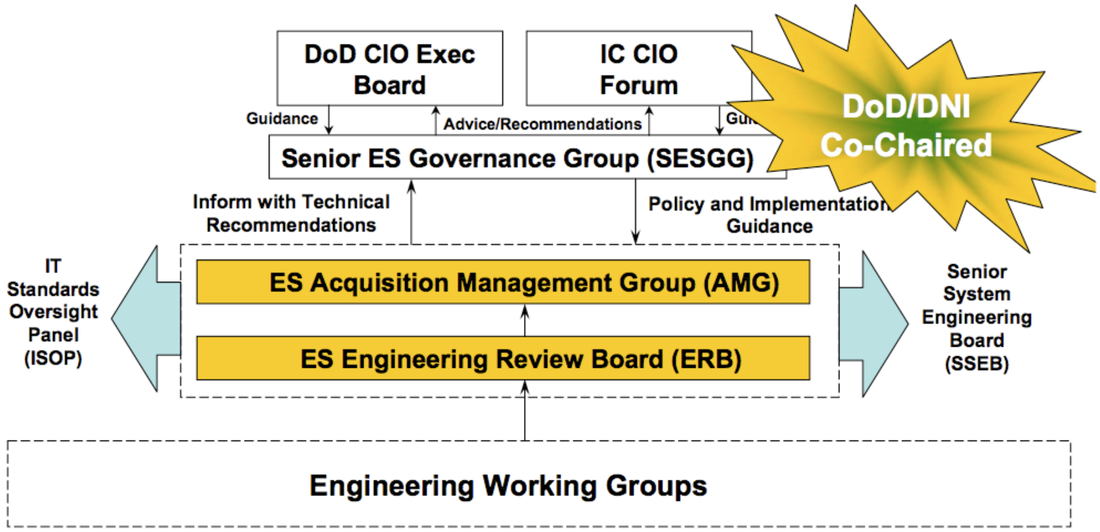

Figure 15. DoD/DNI Enterprise Services Technical Governance Forum from (PEO-C4I, 2008, p. 27).

The DoD CIO and the Director of National Intelligence (DNI) CIO are co-chairing the forum and providing guidance as new recommendations for enterprise services implementation. This is a promising endeavor that may improve joint interoperability. This forum is set up for implementation, but a similar organization must exist to continue to govern each new service as systems evolve. A permanent governance board will ensure joint interoperability continues as new services are added and obsolete services are removed.

2. Cost Savings

The CANES system is currently in an early acquisition phase. Multiple industry days and RFI's have been issued, but the RFP will not be available until August 2008. The Navy is still seeking input from industry before finalizing CANES initial requirements; therefore, funding requirements are not clear at this time. Although funding for CANES is still undetermined, $21.6 million has been allocated to CANES for FY2009 (Roughead, 2008, p. 6). This system is considered "mission critical for the fleet and is a priority for Navy leadership" (SPAWAR, 2008, p. 3). CANES is expected to reduce total ownership costs through the use of SOA and OA. The commercial market

has already shown the cost benefits of using SOA (Erickson, 2006, p. 6). As DoD SOA and OA initiatives materialize, cost savings should be realized through greater commonality and reduced redundancy.

In 2001, AT&T adopted the use of Web-services that would move towards a true SOA by 2003. The initial resistance to using an SOA was solved by AT&T's senior vice president stating "Thou shalt use Web services," and "If you don't use Web services, you'll get fired" (McKendrick, 2006). This example of change management was required to move AT&T towards using a true SOA. The benefits have shown real cost savings within 5 years of starting its SOA initiative. "By 2005 AT&T had documented over $40 million in savings from SOA" (Erickson, 2006, p. 6). AT&T also projects that it will see an additional $100 million in cost savings by 2009. AT&T has benefited from SOA's ability to re-use services, reduce maintenance through reduced interfaces and versioning, and increase commonality across SOA customer interfaces. Figure 16 illustrates the cost savings AT&T was able to achieve by the re-use of a single service across 5 clients.

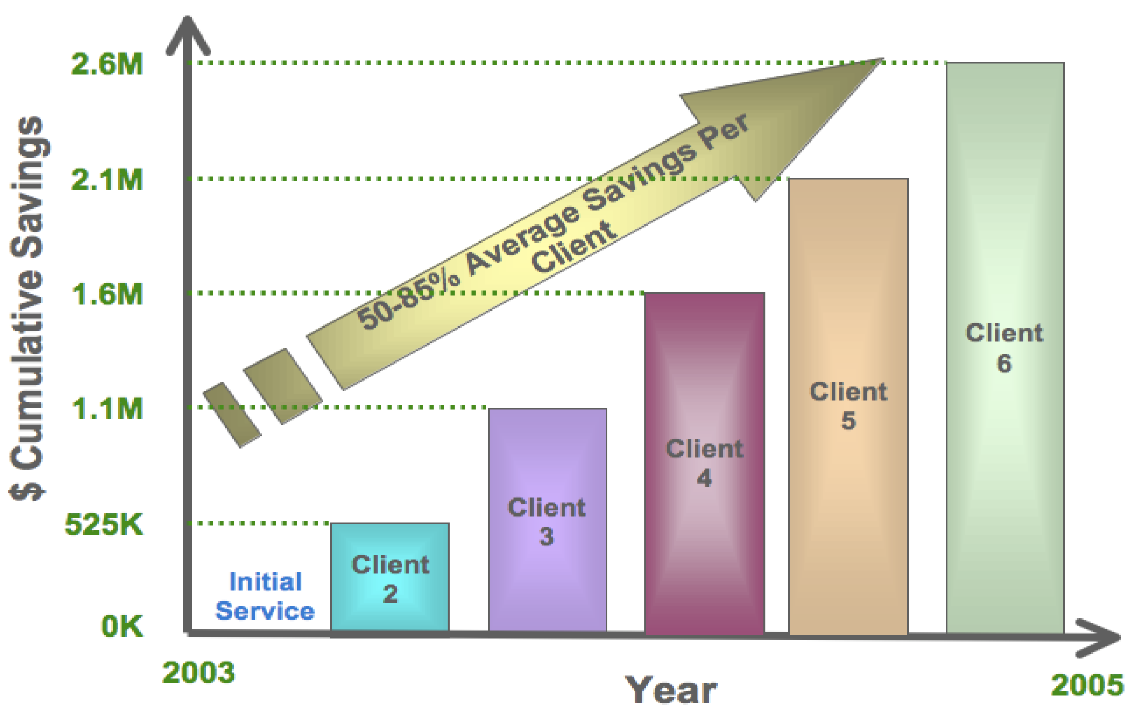

Figure 16. AT&T Cost Savings from (Erickson, 2006, p. 6)

AT&T is a large enterprise that can be compared to the Naval enterprise. The Navy Leadership has already mandated using OA and considers SOA a priority.

> The Consolidated Afloat Networks and Enterprise Services (CANES) system achieves an open, agile, flexible and affordable network architecture that will move us forward. CANES embraces cross-domain solutions that enable enhanced movement of data. It is a revolutionary change in our information technology infrastructure and it is absolutely vital for us to excel in 21st century warfare. (Roughead, 2008, p. 6)

Roughead's statement is similar to the AT&T vice president's statement in that it embraces the use of SOA (through CANES). Just as AT&T has benefited through its SOA implementation, the Navy can expect to achieve similar benefits through its SOA implementation with CANES. As the number of clients/customers of the services provided by AT&T's SOA increases, their cost savings increase. As the Navy implements CANES across different platforms, it too can expect an increase in cost savings. Greater cost savings will accrue as DoD military components increase information sharing among each military service through common SOA interfaces.

E. SUMMARY

This chapter analyzed the Navy's SOA implementation within CANES. The chapter started with a broad overview of CANES and what it is trying to accomplish, then it discussed how the Navy plans to implement SOA within CANES and how it adheres to SOA and OA principles and practices. The chapter then discussed how CANES will utilize SOA and OA to provide future IWS capabilities. This chapter and this case study provided answers to the second and third thesis questions, "Do current Navy OA policies and SOA practices provide the necessary interoperability requirements for future IWS?" and "What benefits might SOA and OA provide to IWS?"

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V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The main purpose of this thesis was to analyze whether the Defense Acquisition System needs to be altered to take advantage of the implementation of Services-oriented Architecture (SOA) and Open Architecture (OA) principles into the acquisition of Integrated Warfare Systems (IWS). The research behind this thesis had several objectives. The researchers began by examining SOA and OA principles and processes to satisfy the first objective of determining the relational architecture between SOA and OA systems. The researchers then examined the Defense Acquisition System and the acquisition lifecycle to satisfy the second objective of determining the feasibility of moving toward SOA and OA systems. This examination of the Defense Acquisition System then lead to satisfying the third objective of identifying any possible constraints within the Defense Acquisition System that would prevent the implementation of SOA and OA in IWS. The researchers examined the Consolidated Afloat Networks and Enterprise Services (CANES) program to satisfy the fourth objective, which was to determine the best practices of a Naval acquisition program that is currently implementing SOA and OA into its acquisition process. Finally, the researchers examined some other Navy and DoD initiatives to satisfy the final objective of establishing some successful realignments of the Defense Acquisition System to allow new technology acquisition in military organizations.

The research objectives of this thesis were established and fulfilled to enable the researchers to answer three thesis questions; “Does the Defense Acquisition System need to be altered to take advantage of SOA and OA implementation into the acquisition lifecycle?”, “Do current Navy OA policies and SOA practices provide the necessary interoperability requirements for future IWS?” and “What benefits might SOA and OA provide to IWS?”

Chapter III provided a detailed examination of the Defense Acquisition System and the answer to the first thesis question, "Does the Defense Acquisition System need to be altered to take advantage of SOA and OA implementation into the acquisition lifecycle?" From the analysis of the current Defense Acquisition System, the researchers conclude that the implementation of SOA and OA does not require a necessity to alter the current processes. The requirement for using a modular open systems approach (MOSA) within the Defense Acquisition System enables rather than inhibits implementing SOA and OA. Although the service delivery lifecycle stages of an SOA do not completely fit with the defense acquisition management framework, the flexibility of the framework allows the procedures and processes to be tailored to meet the needs of implementing an SOA. The *DoDD 5000.1* and *DoDI 5000.2* provide the necessary guidelines for developing and acquiring emerging technologies such as SOA and OA. The emphasis of implementing SOA and OA into future IWS needs to come from the policies and guidance set forth by the Navy. To further OA use within Naval systems, the Navy should begin to combine the use of OA with other emerging technologies such as SOA and service-oriented computing. The Navy must eliminate the traditional "stove-piped" acquisition process (in which each platform acquired its own combat systems) and move toward a horizontal acquisition process in which combat systems are acquired and integrated across multiple platforms.

Chapter IV provided a short analysis of the CANES program and the answers to the second and third thesis questions, "Do current Navy OA policies and SOA practices provide the necessary interoperability requirements for future IWS?" and "What benefits might SOA and OA provide to IWS?" After analysis of the CANES program, the authors concluded that the Navy is proceeding in the correct direction to meet future warfighter needs by using OA and SOA in CANES to support future IWS. Although CANES is still in its infancy as a program, having not yet released an RFP, it is following current SOA and OA policies and practices in order to provide the interoperability requirements the Navy desires for future IWS. As the Navy continues to develop CANES, following commonly accepted SOA methods and best practices will increase the program's success. Since requirements are likely to evolve as CANES development and implementation

progresses, adherence to common SOA and OA principles and practices will provide the necessary interoperability and agility for future IWS. CANES participation in the Multi-Service SOA Consortium is a positive step toward increasing joint interoperability. The potential cost savings benefit from CANES and the increase in information sharing is also evident. As illustrated in Chapter IV, AT&T has demonstrated the benefits of migrating from legacy systems to SOA. Cost savings and improved information sharing will increase the Navy's and the other military services' warfighting capabilities in the future. The CANES program is the first step towards moving from the Navy's current IWS systems to future systems that capitalize on the benefits of utilizing OA and SOA. CANES is an early step toward shifting the Navy's acquisition system from a vertical "stove-piped" process to a more horizontal process that will provide the necessary interoperability requirements for future IWS.

B. RECOMMENDATIONS

Based on their conclusions, the researchers have developed several recommendations that will facilitate the Navy's transition from a vertical "stove-piped" acquisition process to a horizontal acquisition process. The first recommendation is to re-structure the current PEO system. Chapter III discussed the concepts behind the creation of PEO-IWS and the limitations it faces due to current funding structures. In order to create a truly horizontal acquisition process and integrating combat systems across multiple platforms, the Navy should consider re-structuring the current PEO system–providing PEO-IWS with not only the authority and responsibility to design, construct and maintain integrated combat systems, but also to provide them with the proper funding and the control of that funding.

The second recommendation is to establish SOA policies and guidance within the Navy and the DoD. The Navy's policies and guidance concerning OA have begun to catch up with the commercial market and should facilitate the implementation of OA into future combat systems acquisition processes. The DON SOA Transformation Group should capitalize on the current Naval OA policies and guidance when developing its SOA policies and guidance. The Navy will also need to develop a contracting guidebook

for program managers and contracting officers' guidance for implementing SOA into their contracts. Similar to the Navy's OA contract guidebook, the SOA contract guidebook should contain suggested language for Sections C, H, L, and M as well as recommendations that provide incentives to contractors for utilizing SOA. SOA principles and policies combined with OA principles and policies supports horizontal systems engineering and provides a path for the transition from a vertical to a horizontal acquisition process.

The third recommendation is for the DoD to establish a continuous joint SOA governance board led by DoD personnel not affiliated with a particular military service. Joint interoperability is imperative for all future DoD IT systems. SOA standards are currently in development through the Multi-Service SOA Consortium and the Enterprise Services Technical Governance Forum. These organizations are intended to develop common standards to increase the interoperability throughout all military services. Using these organizations increases the likelihood of each military service's SOA program to be interoperable when implemented, but it does not provide the necessary means for maintaining interoperability as systems mature. The establishment of a continuous joint SOA governance board will provide the necessary governance to maintain joint interoperability as systems change. The board will monitor changes to any military SOA program, ensuring new service implementations adhere to approved standards.

VI. FUTURE WORK

While conducting the research and writing for this thesis, the researchers identified several issues that could be developed and addressed by future NPS thesis students.

1. Evaluation of the PEO System

One of the recommendations of the researchers is the re-structuring of the PEO system. One of the limitations facing PEO-IWS is the current funding structure. A thesis could be developed that would evaluate the current PEO system in order to identify constraints within the PEO structure that inhibits the transition from a vertical to a horizontal acquisition process. The thesis could then develop recommendations on how to re-structure the PEO system to enable a horizontal acquisition process.

2. SOA Policy and Guidance Development

Another recommendation provided in this thesis is the development of the Navy's SOA policies and guidance. A thesis student could work directly with the DON SOA Transformation Group to develop a thesis that would provide an evaluation on both the Navy's current OA policies and guidance along with the best practices of the commercial SOA implementations. This thesis could provide recommendations for the development of the Navy's SOA policies and guidance.

3. SOA Contracting Implications

This thesis briefly discussed the similarities between a modular open systems approach (MOSA) acquisition strategy and its implication on the contracting process and the implications of SOA within the contracting process. A graduate student could research and develop a thesis that evaluates the implications of SOA within an acquisition strategy and the contracting process. Since the CANES program is currently developing and revising its acquisition strategy and contracting process, it would provide a case example in which the graduate student could develop his or her thesis.

4. Assess Effectiveness of SOA Implementation

This thesis discussed how the DoD's requirements established for utilization of a MOSA approach enables SOA. Although the Navy has not established policies that require the use of SOA, it still desires to use SOA. One of the recommendations of this thesis was to establish SOA policies within the Navy and DoD. It would be interesting to know, without a current policy requiring the use of SOA, how Program Managers (PM) and Milestone Decision Authorities (MDA) are implementing SOA into their programs. A graduate student could research and develop a thesis that assesses the effectiveness of an SOA implementation by comparing it to the current MOSA implementation within the DoD. If PMs and MDAs are not concerned about SOA implementation, they may not care about the status of utilizing an SOA. The results of this research may support the need for the Navy and DoD to establish policies that require the use of SOA similar to those policies established for the requirement to use MOSA.

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